2D Matlab basics

```
clear, close all, clc
set_defaults()
```

In two dimensions we will extensively use two functions for plotting:

1. meshgrid()
2. reshape()

These functions have an internal logic that is counter-intuitive and forces us to use certain convections to avoid trouble later.

Meshgrid()

The function meshgrid() takes two vectors **x** and **y** that contain the location of the grid points and generates matrices **X** and **Y** that are used by all 2D Matlab plotting functions, in particular contour()/contourf() and surf().

```
f = @(x,y) x.*y;
g = @(x,y) y;

Nx = 4; Ny = 3; N = Nx*Ny
```

```
N = 12
```

```
x = linspace(0,1,Nx)
```

```
x = 1×4
         0    0.3333    0.6667    1.0000
```

```
y = linspace(0,2,Ny)
```

```
y = 1×3
     0     1     2
```

```
[X,Y] = meshgrid(x,y)
```

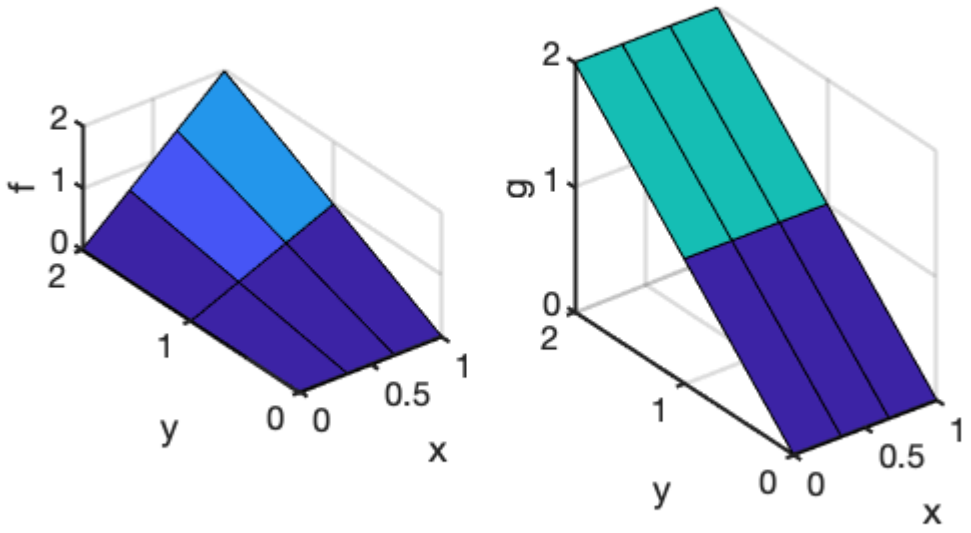
```
X = 3×4
         0    0.3333    0.6667    1.0000
         0    0.3333    0.6667    1.0000
         0    0.3333    0.6667    1.0000
Y = 3×4
     0     0     0     0
     1     1     1     1
     2     2     2     2
```

```
size(X)
```

```
ans = 1×2
     3     4
```

In the matrices **X** and **Y**, the y-value increases with the row index, i, and the x-value increases with the column index, j. Since we index matrices as **X**(i,j) and **Y**(i,j), the first index is the y-coordinate. This makes it natural to order our grid y-first - see below!

```
subplot 121
surf(X,Y,f(X,Y))
xlabel 'x', ylabel 'y', zlabel 'f'
pbaspect([1 2 .8])

subplot 122
surf(X,Y,g(X,Y))
xlabel 'x', ylabel 'y', zlabel 'g'
pbaspect([1 2 2*.8])
```



Reshape()

The solution of the PDE is calculated as a column vector, **u**. To plot the solution **u** has to be reshaped into a matrix that is compatible with the ordering of the **X** and **Y** matrices produced by meshgrid. The Matlab function reshape() allows us to move from vectors to matrices and back.

1) From a matrix to a vector

There are two options to turn a matrix into a column vector.

1. Colon operator

2. reshape()

```
X
```

```
X = 3×4
         0    0.3333    0.6667    1.0000
         0    0.3333    0.6667    1.0000
         0    0.3333    0.6667    1.0000
```

```
x1 = X(:)
```

```
x1 = 12×1
         0
         0
         0
    0.3333
    0.3333
    0.3333
    0.6667
    0.6667
    0.6667
    1.0000
    ⋮
```

```
x2 = reshape(X,N,1)
```

```
x2 = 12×1
         0
         0
         0
    0.3333
    0.3333
    0.3333
    0.6667
    0.6667
    0.6667
    1.0000
    ⋮
```

Note, both ways stack the columns of **X** into a column.

Of course reshape() is the more general, it allows you to transform X into any matrix or vector with the same number of elements

```
reshape(X,1,N)      % row vector
```

```
ans = 1×12
         0         0         0    0.3333    0.3333    0.3333    0.6667    0.6667 ···
```

```
reshape(X,Nx,Ny)    % flip the dimension of the matrix
```

```
ans = 4×3
         0    0.3333    0.6667
```

```
         0    0.3333    1.0000
         0    0.6667    1.0000
    0.3333    0.6667    1.0000
```

1) From vector to matrix

Suppose the solution is given by $\mathbf{g} = g(\mathbf{x})$

```
soln = g(X(:),Y(:))
```

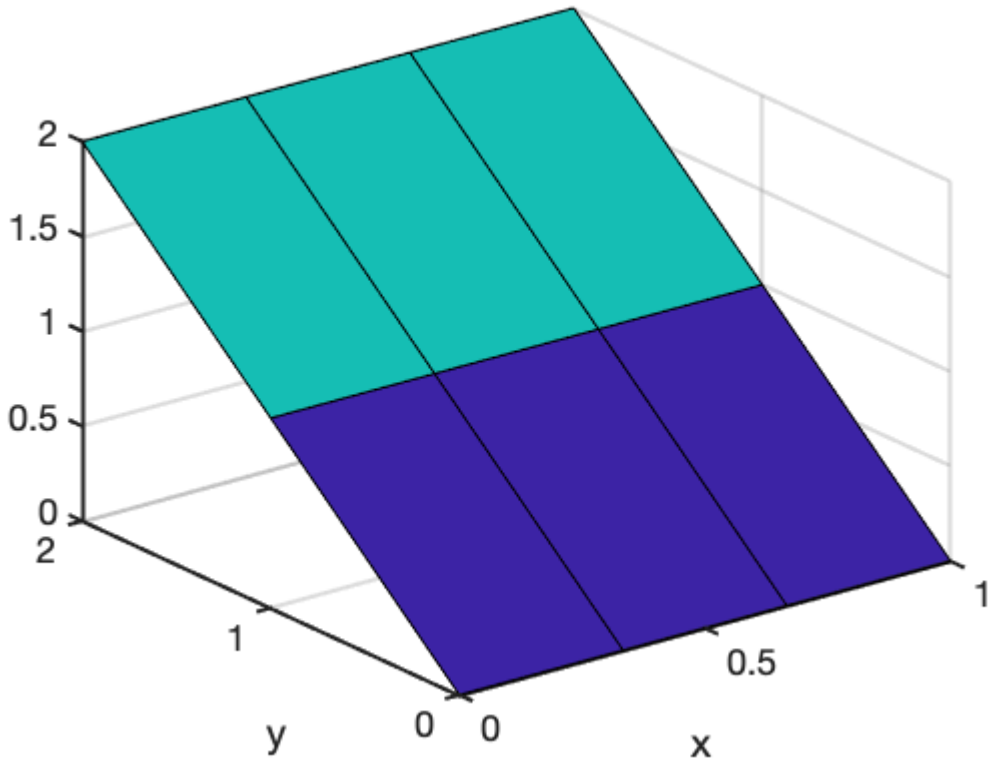
```
soln = 12×1
     0
     1
     2
     0
     1
     2
     0
     1
     2
     0
     ⋮
```

To plot this solution we need to transfer it back to a matrix. To be compatible with X and Y from meshgrid this matrix has to be of size Ny by Nx!

```
SOLN = reshape(soln,Ny,Nx)
```

```
SOLN = 3×4
     0     0     0     0
     1     1     1     1
     2     2     2     2
```

```
figure
surf(X,Y,SOLN)
xlabel('x'), ylabel('y')
```



Notice, that Ny is the first entry, because meshgrid() has a y-first ordering!

2D grid with y-first ordering

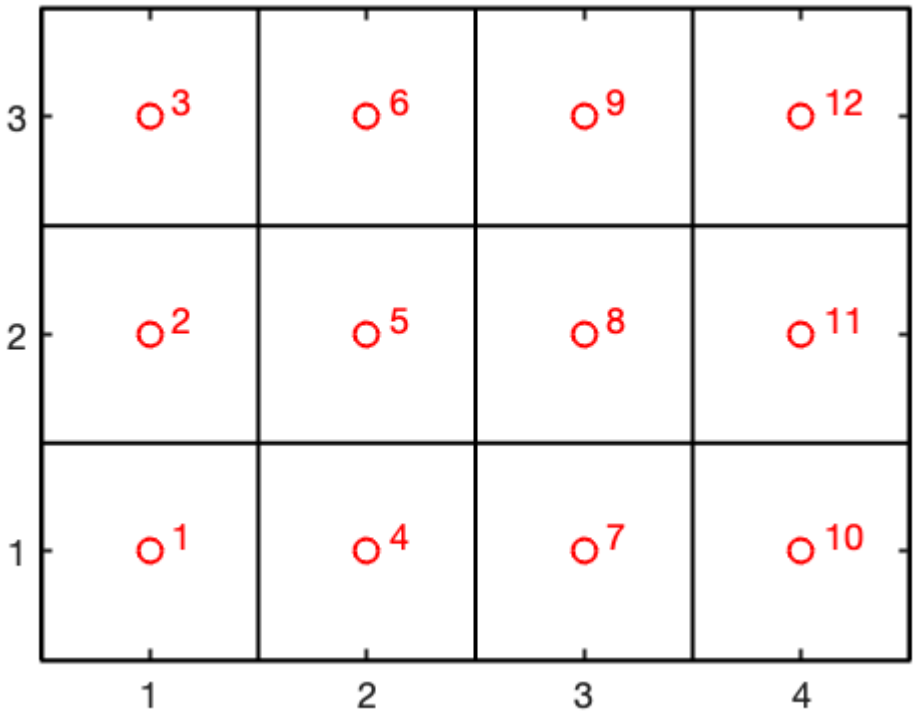
Given that meshgrid() has an internal y-first ordering, we use a computational grid with a y-first ordering. This way we avoid a lot of problems!

```
Nx = 4;
Ny = 3;
N = Nx*Ny;

x = 1:Nx;
y = 1:Ny;
dof = 1:N;

[X,Y] = meshgrid(x,y);

DOF = reshape(dof,Ny,Nx)
```

```
DOF = 3×4
     1     4     7    10
     2     5     8    11
     3     6     9    12
```

```
plot([.5 Nx+.5 Nx+.5 .5 .5],[.5 .5 Ny+.5 Ny+.5 .5],'k'), hold on
```

```
for i=1:Nx
    plot([x(i)+.5 x(i)+.5],[.5 Ny+.5],'k-')
    for j=1:Ny
        plot([.5 Nx+.5],[y(j)+.5 y(j)+.5],'k-')
        plot(X(j,i),Y(j,i),'ro','markerfacecolor','w')
        text(X(j,i)+.1,Y(j,i)+.07,num2str(DOF(j,i)),'fontsize',18,'color','r')
    end
end
set(gca,'xtick',[1:Nx],'ytick',[1:Ny])
axis equal tight
```



Tensor Product

```
A = eye(4);
B = [1 2;...
     4 5];

AoB = kron(A,B)
```

```
AoB = 8×8
     1     2     0     0     0     0     0     0
     4     5     0     0     0     0     0     0
     0     0     1     2     0     0     0     0
     0     0     4     5     0     0     0     0
     0     0     0     0     1     2     0     0
     0     0     0     0     4     5     0     0
     0     0     0     0     0     0     1     2
```

```
     0     0     0     0     0     0     4     5
```

```
BoA = kron(B,A)
```

```
BoA = 8×8
     1     0     0     0     2     0     0     0
     0     1     0     0     0     2     0     0
     0     0     1     0     0     0     2     0
     0     0     0     1     0     0     0     2
     4     0     0     0     5     0     0     0
     0     4     0     0     0     5     0     0
     0     0     4     0     0     0     5     0
     0     0     0     4     0     0     0     5
```

Auxillary functions

set_defaults()

```
function [] = set_defaults()
set(0, ...
    'defaultaxesfontsize',   18, ...
    'defaultaxeslinewidth',   2.0, ...
    'defaultlinelinewidth',   2.0, ...
    'defaultpatchlinewidth',  2.0,...
    'DefaultLineMarkerSize', 12.0);
end
```