Vectors and Plotting

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Initializing Vectors

- colon operator
  - x = 1:2:10
    x =
    1 3 5 7 9
  - y = 0:0.1:0.5
    y =
    0 0.1 0.2 0.3 0.4 0.5
- built-in functions
  - zeros(), ones()

Initializing Vectors

- linspace(x1,x2) generates a row vector of 100 linearly equally spaced points between x1 and x2
- linspace(x1,x2,N) generates N points between x1 and x2
  - x = linspace(10,20,5)
    x =
    10.00 12.50 15.00 17.50 20.00
- logspace(x1,x2) can be used for logarithmically equally spaced points

Vector Input to Functions

- You can call built-in functions with array inputs
- The function is applied to all elements of the array
- The result is an array with the same size as the input array

Vector Input to Functions

- Examples:
  - x = [3 -2 9 4 -5 6 2];
  - abs(x)
    ans =
    3 2 9 4 5 6 2
  - sin([0 pi/6 pi/4 pi/3 pi/2])
    ans =
    0 0.5000 0.7071 0.8660 1.0000
  - a = 1:5;
  - log(a)
    ans =
    0 0.6931 1.0986 1.3863 1.6094

Vector Operations

- Scalar-vector operations
  - x = 1:5
    x =
    1 2 3 4 5
  - y = 2 * x ← scalar multiplication
    y =
    2 4 6 8 10
  - z = x + 10 ← scalar addition
    z =
    11 12 13 14 15

Vector Operations

- Vector-vector operations (element-by-element operations)
  - x = [1 2 3 4 5];   y = [2 -1 4 3 -2];
  - z = x + y
    ```
    z =
         3     1     7     7     3
    ```
  - z = x .* y
    ```
    z =
         2    -2    12    12   -10
    ```
  - z = x ./ y
    ```
    z =
        0.5000   -2.0000    0.7500    1.3333   -2.5000
    ```


Vector Operations

- Vector-vector operations (element-by-element operations)
  - z = x .^ y
  - z =
    1.00   0.50   81.00   64.00   0.04
- Use .*, ./, .^ for element-by-element operations
- Vector dimensions must be the same

Loops vs. Vectorization

- Problem: Find the maximum value in a vector
  - Soln. 1: Write a loop
  - Soln. 2: Use the built-in function "max"
- Use built-in MATLAB functions as much as possible instead of reimplementing them

Loops vs. Vectorization

```
%Compares execution times of loops and vectors
%
%by Selim Aksoy, 7/3/2004

%Create a vector of random values
x = rand(1,10000);

%Find the maximum value using a loop
tic;                %reset the time counter
m = 0;
for ii = 1:length(x),
    if ( x(ii) > m ),
        m = x(ii);
    end
end
t1 = toc;           %elapsed time since last call to tic

%Find the maximum using the built-in function
tic;                %reset the time counter
m = max(x);
t2 = toc;           %elapsed time since last call to tic

%Display timing results
fprintf( 'Timing for loop is %f\n', t1 );
fprintf( 'Timing for built-in function is %f\n', t2 );
```


Loops vs. Vectorization

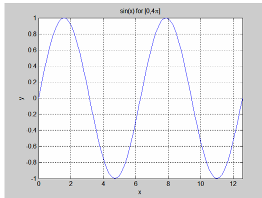
- Problem: Compute $3x^2+4x+5$ for a given set of values
  - Soln. 1: Write a loop
  - Soln. 2: Use 3*x.^2 + 4*x + 5
- Allocate all arrays used in a loop before executing the loop
- If it is possible to implement a calculation either with a loop or using vectors, always use vectors

Loops vs. Vectorization

```
%Compares execution times of loops and vectors
%
%by Selim Aksoy, 7/3/2004

%Use a loop
tic;                %reset the time counter
clear y;
for x = 1:10000,
    y(x) = 3 * x^2 + 4 * x + 5;
end
t1 = toc;           %elapsed time since last call to tic

%Use a loop again but also initialize the result vector
tic;                %reset the time counter
clear y;
y = zeros(1,10000);
for x = 1:10000,
    y(x) = 3 * x^2 + 4 * x + 5;
end
t2 = toc;           %elapsed time since last call to tic

%Use vector operations
tic;                %reset the time counter
clear y;
x = 1:10000;
y = 3 * x.^2 + 4 * x + 5;
t3 = toc;           %elapsed time since last call to tic

%Display timing results
fprintf( 'Timing for uninizialed vector is %f\n', t1 );
fprintf( 'Timing for inizialed vector is %f\n', t2 );
fprintf( 'Timing for vectorization is %f\n', t3 );
```

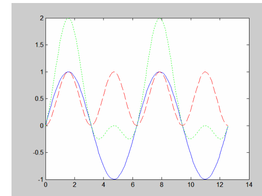
Plotting

```
x = linspace(0, 4*pi);
y = sin(x);
plot(x,y);
title( 'sin(x) for [0,4\pi]' );
xlabel( 'x' );
ylabel( 'y' );
grid on;
axis( [ 0 4*pi -1 1 ] );
```



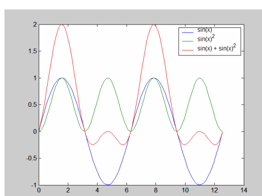
Plotting: Multiple Graphs

```
x = linspace(0, 4*pi);
y1 = sin(x);
y2 = sin(x) .^ 2;
y3 = y1 + y2;
plot(x,y1,'b-');
hold on;
plot(x,y2,'r--');
plot(x,y3,'g:');
hold off;
```



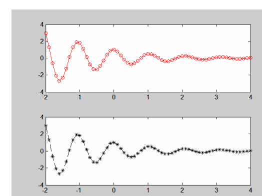
Plotting: Multiple Graphs

```
x = linspace(0, 4*pi);
y1 = sin(x);
y2 = sin(x) .^ 2;
y3 = y1 + y2;
plot(x,y1,x,y2,x,y3);
legend( 'sin(x)', ...
   'sin(x)^2', ...
   'sin(x) + sin(x)^2' );
```



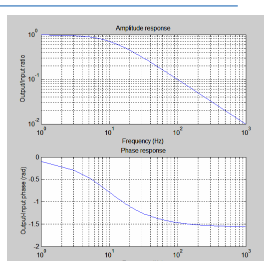
Plotting: Subplots

```
x = -2:0.1:4;
y = 3.5 .^ (-0.5*x) .* ...
   cos(6*x);
figure(1);
subplot(2,1,1);
plot(x,y,'r-o');
subplot(2,1,2);
plot(x,y,'k--*');
print -f1 -dtiff myplot.tif
```



Plotting: Logarithmic Plots

```
r = 16000; c = 1.0e-6;
f = 1:2:1000;
res = 1 ./ ( 1 + j*2*pi*f*r*c );
amp = abs(res);
phase = angle(res);
subplot(2,1,1);
loglog(f,amp);
title( 'Amplitude response' );
xlabel( 'Frequency (Hz)' );
ylabel( 'Output/Input ratio' );
grid on;
subplot(2,1,2);
semilogx(f,phase);
title( 'Phase response' );
xlabel( 'Frequency (Hz)' );
ylabel( 'Output-Input phase (rad)' );
grid on;
```



Plotting Summary

- plot(x,y)
  linear plot of vector y vs. vector x
- title('text'), xlabel('text'), ylabel('text')
  labels the figure, x-axis and y-axis
- grid on/off
  adds/removes grid lines
- legend('string1', 'string2', 'string3', ...)
  adds a legend using the specified strings
- hold on/off
  allows/disallows adding subsequent graphs to the current graph

Plotting Summary

- axis([xmin xmax ymin ymax])
  sets axes' limits
- v = axis
  returns a row vector containing the scaling for the current plot
- axis equal
  sets the same scale for both axes
- axis square
  makes the current axis square in size

Plotting Summary

line color		line marker		line style	
b	blue	.	point	-	solid
g	green	o	circle	:	dotted
r	red	x	x-mark	-.	dashdot
c	cyan	+	plus	--	dashed
m	magenta	*	star		
y	yellow	s	square		
k	black	d	diamond		
		v	triangle (down)		
		^	triangle (up)		
		<	triangle (left)		
		>	triangle (right)		
		p	pentagram		
		h	hexagram		

Plotting Summary

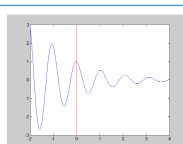
- semilogy(x,y), semilogx(x,y), loglog(x,y)
  logarithmic plots of vector y vs. vector x
- figure(k)
  makes k the current figure
- subplot(m,n,p)
  breaks the figure window into an m-by-n matrix of small axes and selects the pth axes for the current plot
- clf
  clears current figure

Plotting Summary

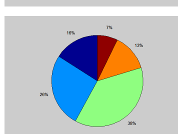
- print –f<handle> -d<device> <filename>
  saves the figure with the given handle in the format specified by the device
  - -deps Encapsulated PostScript
  - -depsc Encapsulated Color PostScript
  - -deps2 Encapsulated Level 2 PostScript
  - -depsc2 Encapsulated Level 2 Color PostScript
  - -djpeg<nn> JPEG image with quality level of nn
  - -dtiff TIFF image
  - -dpng Portable Network Graphics image

Plotting Examples

- Line plot
  ```
  x = -2:0.01:4;
  y = 3.5.^(-0.5*x).*cos(6*x);
  plot(x,y);
  line([0 0],[-3 3],'color','r');
  ```

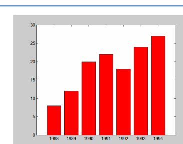


- Pie plot
  ```
  grades = [ 11 18 26 9 5 ];
  pie(grades);
  ```

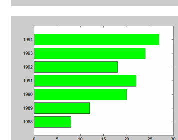


Plotting Examples

- Vertical bar plot
  ```
  y = 1988:1994;
  s = [ 8 12 20 22 18 24 27 ];
  bar(y,s,'r');
  ```

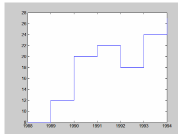


- Horizontal bar plot
  ```
  y = 1988:1994;
  s = [ 8 12 20 22 18 24 27 ];
  barh(y,s,'g');
  ```

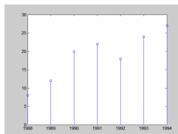


Plotting Examples

- Stairs plot
  y = 1988:1994;
  s = [8 12 20 22 18 24 27];
  stairs(y,s);

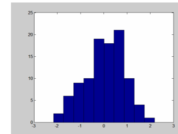


- Stem plot
  y = 1988:1994;
  s = [8 12 20 22 18 24 27];
  stem(y,s);

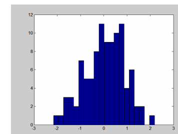


Plotting Examples

- Histogram
  x = randn(1,100);
  hist(x,10);

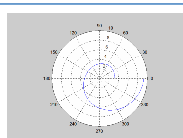


hist(x,20);

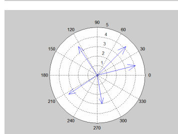


Plotting Examples

- Polar plot
  t = linspace(0,2*pi,200);
  r = 3 * cos(0.5*t).^2 + t;
  polar(t,r);



- Compass plot
  u = [3 4 -2 -3 0.5];
  v = [3 1 3 -2 -3];
  compass(u,v);



Plotting Examples

- Error bar plot
  x = 1:10;
  y = sin(x);
  e = std(y) * ones(size(x));
  errorbar(x,y,e);