Octave/Matlab Tutorial

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v.1.0, koa, Oct 09

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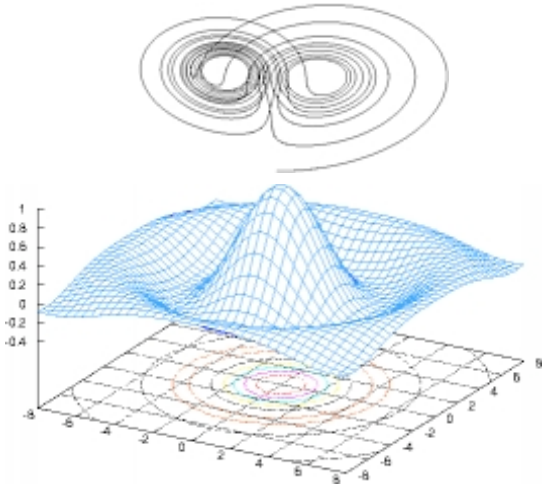
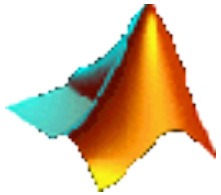


Octave



Matlab

Overview

Octave is the "open-source **Matlab**"

Octave is a great gnuplot wrapper

- www.octave.org
- www.mathworks.com

Octave and **Matlab** are both, high-level languages and mathematical programming environments for:

- Visualization
- Programming, algorithm development
- Numerical computation: linear algebra, optimization, control, statistics, signal and image processing, etc.

Beware: Octave/Matlab programs can be **slow.**

Overview

Matlab-Octave **comparison**:

- Matlab is more flexible/advanced/powerful/costly
- Octave is for free (GPL license)
- There are minor differences in syntax

This tutorial:

- **This tutorial applies to Octave *and* Matlab** unless stated otherwise!

Current versions (autumn 2009):

- Octave 3.2.3
- Matlab 7.6

Contents

Start, Quit, Getting Help

- To **start Octave** type the shell command `octave`, double-click *Octave.app* or whatever your OS needs.
  You should see the prompt:

  ```
  octave:1>
  ```

- If you get into trouble, you can **interrupt Octave** by typing `Ctrl-C`.

- To **exit Octave**, type `quit` or `exit`.

Start, Quit, Getting Help

- To get **help,** type `help` or `doc`
- To get **help** on a **specific command** (=built-in function), type `help command`
- Examples: `help size, help plot, help figure, help inv, ...`
- To get **help** on the help system, type `help help`
- Type `q` to exit help mode (alike man pages)

Start, Quit, Getting Help

- In the help text of Matlab functions, function names and variables are in **capital letters**.
  ➛ Don't get confused! The (case-sensitive) naming convention specifies **lowercase letters** for built-in commands. It is just a way to highlight text.

- Example: `help round` returns

```
ROUND  Round towards nearest integer.

  ROUND(X) rounds the elements of X to the nearest
  integers.

  See also floor, ceil, fix.

  [...]
```

- Octave texts are mixed, in lower- and uppercase.

Contents

Variables and Data Types

- **Matrices** (real and complex)
- **Strings** (matrices of characters)
- **Structures**

➔ Vectors? It's a matrix with one column/row

➔ Scalars? It's a matrix of dimension 1x1

➔ Integers? It's a double (you never have to worry)

➔ Boolean? It's an integer (non-null=true, 0=false)

Almost everything is a **matrix**!

Matlab has more types, e.g. OO-classes

Variables and Data Types

Creating a Matrix

- Simply type:

```
octave:1> A = [8, 2, 1; 3, -1, 4; 7, 6, -5]
```

Octave will respond with a matrix in pretty-print:

```
A =

    8    2    1
    3   -1    4
    7    6   -5
```

➛ More on matrices, further down this tutorial.

Variables and Data Types

Creating a Character String

- Simply type:

```
octave:4> str = 'Hello World'
```

Opposed to Matlab, Octave can also deal with double quotes. For compatibility reasons, **use single quotes**.

Creating a Structure

- Type for instance:

```
octave:5> data.id = 3;
octave:6> data.timestamp = 1265.5983;
octave:7> data.name = 'sensor 1 front';
```

Variables and Data Types

Creating a Array of Structures

- Oh, a new measurement arrives. Extend struct by:

```
octave:8> data(2).id = 4;
octave:9> data(2).timestamp = 1268.9613;
octave..> data(2).name = 'sensor 1 front';
```

Octave will respond with:

```
data =
{
  1x2 struct array containing the fields:
    id
    timestamp
    name
}
```

Variables and Data Types

Display Variables

- Simply type its name:

```
octave:1> a
a = 4
```

Suppress Output

- Add a semicolon:

```
octave:2> a;
octave:3> sin(phi);
```

Applies also to function calls.

Variables and Data Types

- **Variables** have **no permanent type.**

  `s = 3` followed by `s = 'octave'` is fine

- Use `who` (or the more detailed `whos`) to **list** the **currently defined variables**. Example output:

```
Variables in the current scope:

  Attr Name        Size                     Bytes  Class
  ==== ====        ====                     =====  =====
       A           3x3                         72  double
       a           1x1                          8  double
       ans        21x1                        168  double
       s           1x5                          5  char
       v           1x21                        24  double
```

Variables and Data Types

Numerical Precision

Variables are stored as double precision numbers in IEEE floating point format.

- `realmin` Smallest positive floating point number: 2.23e-308
- `realmax` Largest positive floating point number: 1.80e+308
- `eps` Relative precision: 2.22e-16

Variables and Data Types

Control Display of Float Variables

- `format short` — Fixed point format with 5 digits
- `format long` — Fixed point format with 15 digits
- `format short e` — Floating point format, 5 digits
- `format long e` — Floating point format, 15 digits
- `format short g` — Best of fixed or floating point with 5 digits **(good choice)**
- `format long g` — Best of fixed or floating point with 15 digits

See `help format` for more information

Variables and Data Types

Talking about Float Variables…

- `ceil(x)` — Round to smallest integer not less than x
- `floor(x)` — Round to largest integer not greater than x
- `round(x)` — Round towards nearest integer
- `fix(x)` — Round towards zero

If x is a matrix, the functions are applied to each element of x.

Contents

Matrices

Creating a Matrix

- Simply type:

```
octave:1> A = [8, 2, 1; 3, -1, 4; 7, 6, -5]
```

- To delimit **columns**, use comma or space
- To delimit **rows**, use semicolon

The following expressions are equivalent:

```
A = [8 2 1;3 -1 4;7 6 -5]
A = [8,2,1;3,-1,4;7,6,-5]
```

Matrices

Creating a Matrix

- Octave will respond with a matrix in pretty-print:

```
A =

    8    2    1
    3   -1    4
    7    6   -5
```

- Alternative Example:

```
octave:2> phi = pi/3;
octave:3> R = [cos(phi) -sin(phi); sin(phi) cos(phi)]
R =

    0.50000  -0.86603
    0.86603   0.50000
```

Matrices

Creating a Matrix from Matrices

```
octave:1> A = [1 1 1; 2 2 2];  B = [33; 33];
```

- Column-wise

```
octave:2> C = [A B]
C =
    1    1    1   33
    2    2    2   33
```

- Row-wise:

```
octave:3> D = [A; [44 44 44]]
D =
    1    1    1
    2    2    2
   44   44   44
```

Matrices

Indexing

Always "row before column"!

- `aij = A(i,j)` Get an element
- `r = A(i,:)` Get a row
- `c = A(:,j)` Get a column
- `B = A(i:k,j:l)` Get a submatrix

- **Useful indexing command** `end` **:**

```
octave:1> data = [4 -1 35 9 11 -2];
octave:2> v = data(3:end)
v =
    35   9   11   -2
```

Matrices

Colon ':', two meanings:

- **Wildcard** to select **entire** matrix **row** or **column**

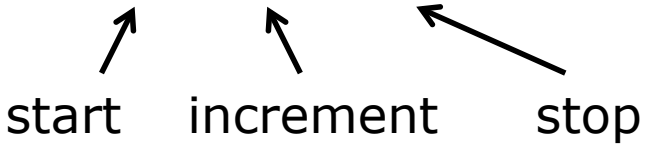
```
A(3,:), B(:,5)
```

- **Defines a *range*** in expressions like

```
indices = 1:5
```
Returns row vector 1,2,3,4,5

```
steps = 1:3:61
```
Returns row vector 1,4,7,...,61

```
t = 0:0.01:1
```
Returns vector 0,0.01,0.02,...,1



- **Useful command** to define ranges: `linspace`

Matrices

Assigning a Row/Column

- All referenced elements are set to the scalar value.

```
octave:1> A = [1 2 3 4 5; 2 2 2 2 2; 3 3 3 3 3];
octave:2> A(3,:) = -3;
```

Adding a Row/Column

- If the referenced row/colum doesn't exist, it's added.

```
octave:3> A(4,:) = 4
A =
    1    2    3    4    5
    2    2    2    2    2
   -3   -3   -3   -3   -3
    4    4    4    4    4
```

Matrices

Deleting a Row/Column

- Assigning an empty matrix `[]` deletes the referenced rows or columns. Examples:

```
octave:4> A(2,:) = []
A =
    1    2    3    4    5
   -3   -3   -3   -3   -3
    4    4    4    4    4

octave:4> A(:,1:2:5) = []
A =
    2    4
    2    2
   -3   -3
    4    4
```

Matrices

Get Size

- `nr = size(A,1)` Get number of rows of A
- `nc = size(A,2)` Get number of columns of A
- `[nr nc] = size(A)` Get both (remember order)
- `l = length(A)` Get whatever is bigger
- `numel(A)` Get number of elements in A
- `isempty(A)` Check if A is empty matrix []

Octave only:

- `nr = rows(A)` Get number of rows of A
- `nc = columns(A)` Get number of columns of A

Matrices

Matrix Operations

- `B = 3*A` — Multiply by scalar
- `C = A*B + X - D` — Add and multiply
- `B = A'` — Transpose A
- `B = inv(A)` — Invert A
- `s = v'*Q*v` — Mix vectors and matrices

- `d = det(A)` — Determinant of A
- `[v lambda] = eig(A)` — Eigenvalue decomposition
- `[U S V] = svd(A)` — Sing. value decomposition

- many many more...

Matrices

Vector Operations

With `x` being a column vector

- `s = x'*x` Inner product, result is a scalar
- `X = x*x'` Outer product, result is a matrix
- `e = x*x` Gives an error

Element-Wise Operations (for vectors/matrices)

- `s = x.+x` Element-wise addition
- `p = x.*x` Element-wise multiplication
- `q = x./x` Element-wise division
- `e = x.^3` Element-wise power operator

Matrices

Useful Vector Functions

- `sum(v)` Compute sum of elements of v
- `cumsum(v)` Compute cumulative sum of elements of v
- `prod(v)` Compute product of elements of v
- `cumprod(v)` Compute cumulative product of elements of v
- `diff(v)` Compute difference of subsequent elements [v(2)-v(1) v(3)-v(2) ...]
- `mean(v)` Mean value of elements in v
- `std(v)` Standard deviation of elements

Matrices

Useful Vector Functions

- `min(v)` Return smallest element in v
- `max(v)` Return largest element in v

- `sort(v,'ascend')` Sort in ascending order
- `sort(v,'descend')` Sort in descending order

- `find(v)` Return vector of indices of all non-zero elements in v. Great in combination with **vectorized conditions**. Example:

```
ivec = find(datavec == 5).
```

Matrices

Special Matrices

- `A = zeros(m,n)` — Zero matrix of size m x n
- `B = ones(m,n)` — Matrix of size m x n with all 1's
- `I = eye(n)` — Identity matrix of size n
- `D = diag([a b c])` — Diagonal matrix of size 3 x 3 with a,b,c in the main diagonal

Just for fun

- `M = magic(n)` — Magic square matrix of size n x n. (All rows and columns sum up to the same number)

Matrices

Random Matrices and Vectors

- `R = rand(m,n)` — Matrix with m x n uniformly distributed random numbers from interval [0..1]
- `N = randn(m,n)` — Row vector with m x n normally distributed random numbers with zero mean, unit variance
- `v = randperm(n)` — Row vector with a random permutation of the numbers 1 to n

Matrices

Multi-Dimensional Matrices

Matrices can have more than two dimensions.

- **Create a 3-dimensional matrix** by typing, e.g.,

```
octave:1> A = ones(2,5,2)
```

Octave will respond by

```
A =
ans(:,:,1) =
   1   1   1   1   1
   1   1   1   1   1
ans(:,:,2) =
   1   1   1   1   1
   1   1   1   1   1
```

Matrices

Multi-Dimensional Matrices

- All operations to **create, index, add, assign, delete and get size** apply **in the same fashion**

Examples:

- `[m n l] = size(A)`
- `A = rand(m,n,l)`
- `m = min(min(min(A)))`
- `aijk = A(i,j,k)`
- `A(:,:,5) = -3`

Matrices

Matrix Massage

- `reshape(A,m,n)` — **Change size** of matrix A to have dimension m x n. An error results if A does not have m x n elements
- `circshift(A,[m n])` — **Shift elements** of A m times in row dimension and n times in column dimension
- `shiftdim(A,n)` — Shift the dimension of A by n. **Generalizes transpose** for multi-dimensional matrices

Matrices

Matrix Massage Example

Let P = [x1; y1; x2; y2; ...] be a 2nx1 column vector of n (x,y)-pairs. Make it a column vector of (x,y,theta)-tuples with all theta values being pi/2:

- Make it a 2xn matrix

```
octave:1> P = reshape(P,2,numel(P)/2);
```

- Add a third row, assign pi/2

```
octave:2> P(3,:) = pi/2;
```

- Reshape it to be a 3nx1 column vector

```
octave:3> P = reshape(P,numel(P),1);
```

Strings

Most Often Used Commands

- `strcat` Concatenate strings
- `int2str` Convert integer to a string
- `num2str` Convert numbers to a string
- `sprintf` Write formatted data to a string. Same as C/C++ fprintf for strings.

- **Example**

```
s = strcat('At step ',int2str(k),', p = ',num2str(p,4))
```

Given that strings are matrices of chars, this is also

```
s = ['At step ' int2str(k) ', p = ' num2str(p,4)]
```

Octave responds with

```
s = At step 56, p = 0.142
```

Strings

Octave/Matlab has **virtually all common string and parsing functions.**

- You are encouraged to browse through the list of commands or simply type `help command` :

  `strcmp, strncmp, strmatch, char, ischar, findstr, strfind, str2double, str2num, num2str, strvcat, strtrim, strtok, upper, lower,`

  and many more...

Contents

Plotting

Plotting in 2D

- `plot(x,cos(x))` Display x,y-plot

Creates automatically a figure window. Octave uses **gnuplot** to handle graphics.

- `figure(n)` Create figure window 'n'

If the figure window **already exists**, brings it into the foreground (= makes it the current figure)

- `figure` Create new figure window with identifier incremented by 1.

Plotting

Several Plots

- Series of x,y-patterns: `plot(x1,y1,x2,y2,...)`

  e.g. `plot(x,cos(x),x,sin(x),x,x.^2)`

- Add **legend** to plot: command `legend`

  ```
  legend('cos(x)','sin(x)','x^2')
  ```

- Alternatively, `hold on` does the same job:

  ```
  octave:1> hold on; plot(x,cos(x));
  octave:2> plot(x,sin(x));
  octave:3> plot(x,x.^2);
  ```

Plotting

Frequent Commands

`clf`	Clear figure
`hold on`	Hold axes. Don't replace plot with new plot, superimpose plots
`grid on`	Add grid lines
`grid off`	Remove grid lines
`title('Exp1')`	Set title of figure window
`xlabel('time')`	Set label of x-axis
`ylabel('prob')`	Set label of y-axis
`subplot`	Put several plot axes into figure

Plotting

Controlling Axes

- `axis equal` — Set equal scales for x-/y-axes
- `axis square` — Force a square aspect ratio
- `axis tight` — Set axes to the limits of the data
- `a = axis` — Return current axis limits `[xmin xmax ymin ymax]`
- `axis([-1 1 2 5])` — Set axis limits (freeze axes)
- `axis off` — Turn off tic marks

- `box on` — Adds a box to the current axes
- `box off` — Removes box

Plotting

Choosing Symbols and Colors

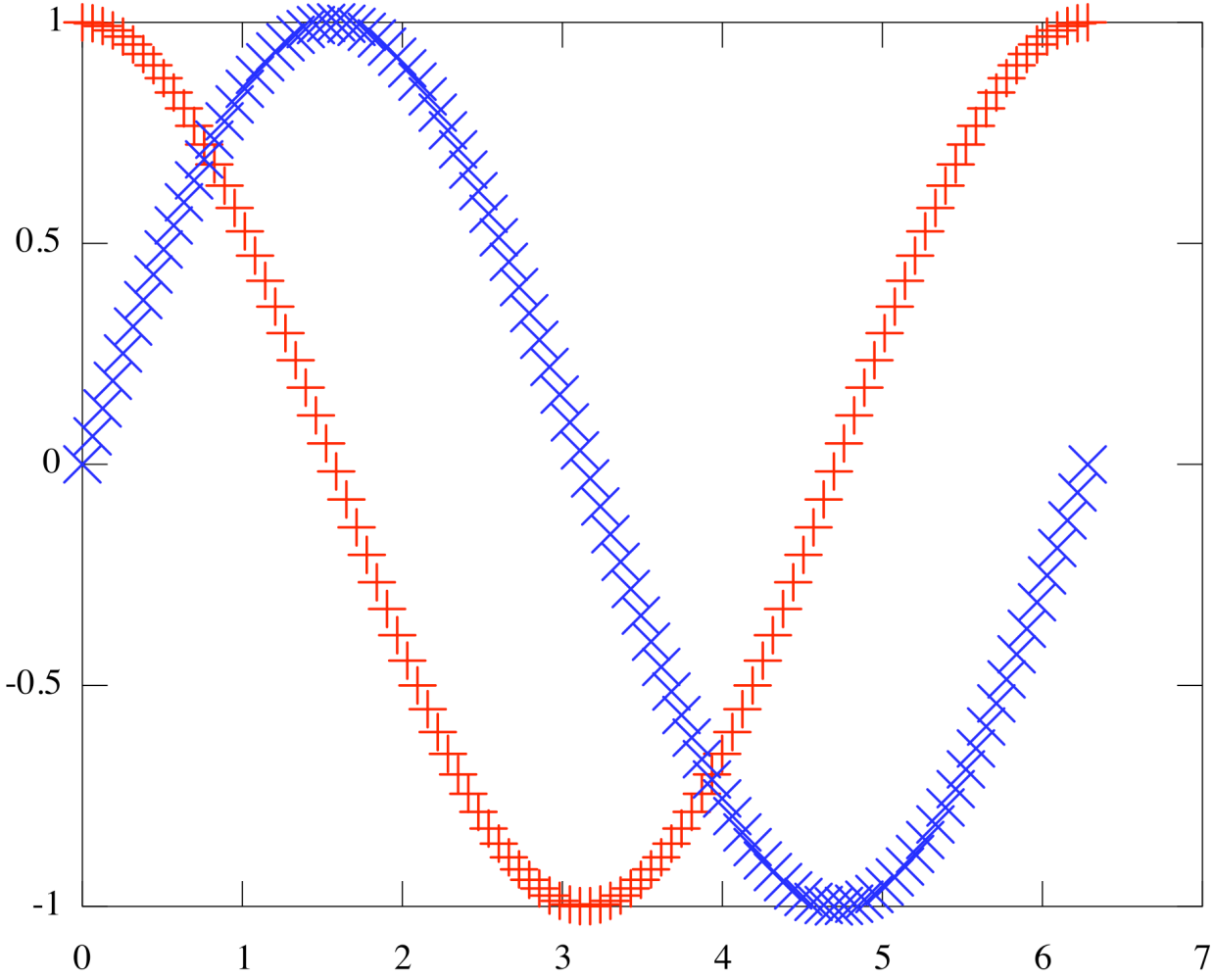
- In `plot(x,cos(x),'r+')` the format expression `'r+'` means *red cross.*
- There are a **number of line styles and colors**, see `help plot`.

Example:

```
octave:1> x = linspace(0,2*pi,100);
octave:2> plot(x,cos(x),'r+',x,sin(x),'bx');
```

produces this plot:

Plotting




```
plot(x,cos(x),'r+',x,sin(x),'bx');
```

Plotting

- **Adjusting the axes**

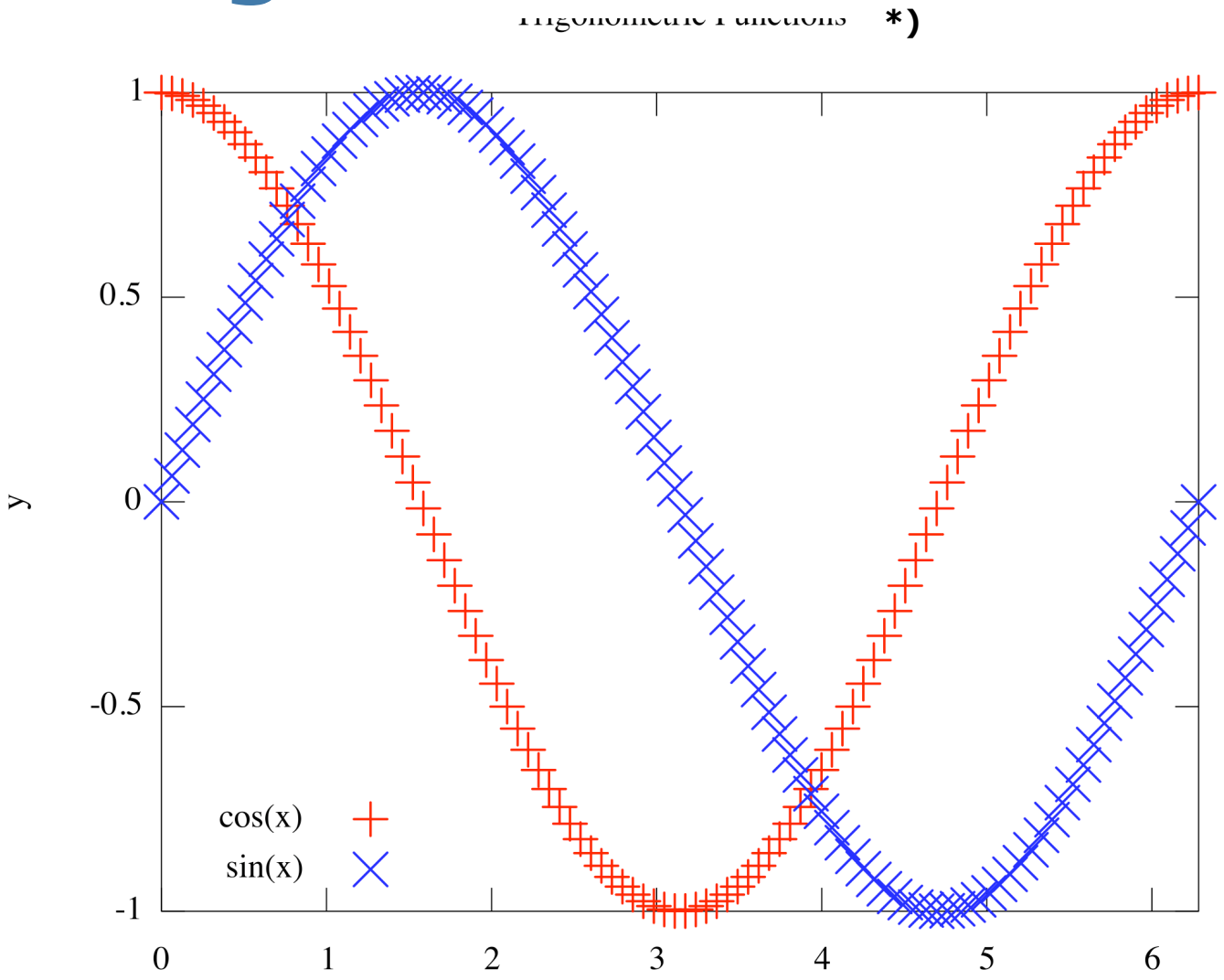
```
octave:3> axis([0 2*pi -1 1])
```

(try also `axis tight`)

- **Adding a legend, labels and a title**

```
octave:4> legend('cos(x)','sin(x)',
  'Location','Southwest')
octave:5> title('Trigonometric Functions')
octave:6> xlabel('x')
octave:7> ylabel('y')
```

Plotting



***)** Title and x-label wrongly cut off. This seems to be a Octave-AquaTerm on Mac problem. Should work in general.

```
plot(x,cos(x),'r+',x,sin(x),'bx');
```

Plotting

Uhm..., don't like it. New try:

```
octave:1> clf;
```

- **Controlling Color and Marker Size**

```
octave:2> plot(x,cos(x),'r+',x,sin(x),'-x',...
'Color',[1 .4 .8],'MarkerSize',2)
```

```
octave:3> axis tight
```

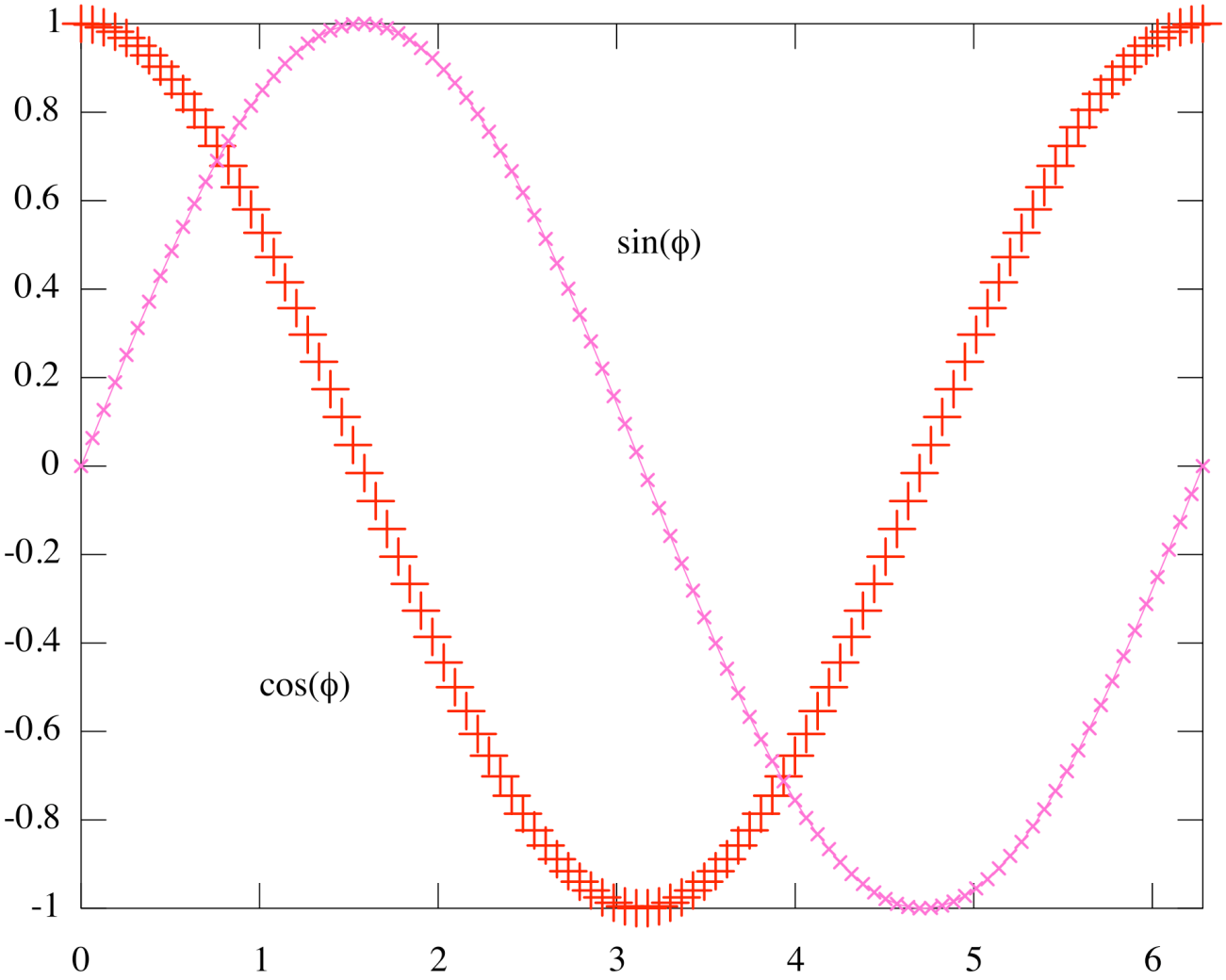
- **Adding Text**

```
octave:4> text(1,-0.5,'cos(\phi)')
```

```
octave:5> text(3,0.5,'sin(\phi)')
```

Note the LateX syntax!

Plotting




```
plot(x,cos(x),'r+',x,sin(x),'-x','Color',[1 .4 .8],'MarkerSize',2)
```

Plotting

Yepp, I like it... Get hardcopy!

Exporting Figures

- `print -deps myPicBW.eps` Export B/W .eps file
- `print -depsc myPic.eps` Export color .eps file
- `print -djpeg -r80 myPic.jpg` Export .jpg in 80 ppi
- `print -dpng -r100 myPic.png` Export .png in 100 ppi

See `help print` for more devices including specialized ones for Latex.

- `print` can also be called **as a function**. Then, it takes arguments and options as a comma-separated list. E.g.: `print('-dpng','-r100','myPic.png');`

Plotting

This tutorial cannot cover the **huge variety of graphics commands** in Octave/Matlab.

- You are encouraged to browse through the list of commands or simply type `help command` :

  `hist, bar, pie, area, fill, contour, quiver, scatter, compass, rose, semilogx, loglog, stem, stairs, image, imagesc`

  and many more...

Plotting

Plotting in 3D

- `plot3` Plot lines and points in 3d
- `mesh` 3D mesh surface plot
- `surf` 3D colored surface plot

Most 2d plot commands have a **3D sibling**. Check out, for example,

```
bar3, pie3, fill3, contour3, quiver3,
scatter3, stem3
```

Contents

Programming

Programming in Octave/Matlab is Super Easy.
However, keep the following facts in mind:

- **Indices start with 1 !!!**

```
octave:1> v = 1:10
octave:2> v(0)
error: subscript indices must be either positive
integers or logicals.
```

- Octave/Matlab is case-sensitive.

Text Editors

- Use an editor with m-file syntax highlighting/ coloring.

Programming

Control Structures

- **`if` Statement**

```
if condition,
  then-body;
elseif condition,
  elseif-body;
else
  else-body;
end
```

The else and elseif clauses are optional.
Any number of elseif clauses may exist.

Programming

Control Structures

- **`switch` Statement**

```
switch expression
  case label
    command-list;
  case label
    command-list;
  ...
  otherwise
    command-list;
end
```

Any number of case labels are possible.

Programming

Control Structures

- **`while` Statement**

```
while condition,
  body;
end
```

- **`for` statement**

```
for var = expression,
  body;
end
```

Programming

Interrupting and Continuing Loops

- `break`

Jumps out of the innermost `for` or `while` loop that encloses it.

- `continue`

Used only inside `for` or `while` loops. It skips over the rest of the loop body, causing the next cycle to begin. Use with care.

Programming

Increment Operators (Octave only!)

Increment operators increase or decrease the value of a variable **by 1**.

- `i++` Increment scalar i by 1
- `i--` Decrement scalar i by 1
- `A++` Increment all elements of matrix A by 1
- `v--` Decrement all elements of vector v by 1

There are the C/C++ equivalent operators `++i` , `--A` .

Programming

Comparison Operators

- All of comparison operators return a **value of 1** if the comparison is **true**, **or 0** if it is **false**.

  Examples: `i == 6, cond1 = (d > theta)`

- For the **matrix-to-matrix** case, the comparison is made on an element-by-element basis. Example:

  `[1 2; 3 4] == [1 3; 2 4]` returns `[1 0; 0 1]`

- For the **matrix-to-scalar** case, the scalar is compared to each element in turn. Example:

  `[1 2; 3 4] == 2` returns `[0 1; 0 0]`

Programming

Comparison Operators

- `any(v)` Returns 1 if **any element** of vector v is **non-zero** (e.g. 1)
- `all(v)` Returns 1 if **all elements** in vector v are **non-zero** (e.g. 1)

For **matrices**, any and all return a row vector with elements corresponding to the columns of the matrix.

- `any(any(C))` Returns 1 if **any element** of matrix C is **non-zero** (e.g. 1)
- `all(all(C))` Returns 1 if **all elements** in matrix C are **non-zero** (e.g. 1)

Programming

Relational Operators

- `x < y` True if x is less than y
- `x <= y` True if x is less than or equal to y
- `x == y` True if x is equal to y
- `x >= y` True if x is greater than or equal to y
- `x > y` True if x is greater than y
- `x ~= y` True if x is not equal to y

- `x != y` True if x is not equal to y (Octave only)
- `x <> y` True if x is not equal to y (Octave only)

Programming

Boolean Expressions

- `B1 & B2` Element-wise logical **and**
- `B1 | B2` Element-wise logical **or**
- `~B` Element-wise logical **not**
- `!B` Element-wise logical not (Octave only)

Short-circuit operations: evaluate expression only as long as needed (more efficient).

- `B1 && B2` Short-circuit logical **and**
- `B1 || B2` Short-circuit logical **or**

Programming

Recommended **Naming Conventions**

- Underscore-separated or lowercase notation for **functions**

  Examples: `intersect_line_circle.m`, `drawrobot.m`, `calcprobability.m`

- UpperCamelCase for **scripts**

  Examples: `LocalizeRobot.m`, `MatchScan.m`

- Note: Matlab/Octave commands are all in lowercase notation (no underscores or dashes)

  Examples: `continue`, `int2str`, `isnumeric`

Contents

Functions and Scripts

Functions

Complicated Octave/Matlab programs can often be simplified by **defining functions**. Functions are typically defined in **external files**, and can be called just like built-in functions.

- In its simplest form, the definition of a function named name looks like this:

```
function name
  body
end
```

- Get used to the principle to define **one function per file** (text files called m-file or .m-file)

Functions and Scripts

Passing Parameters to/from Functions

- Simply write

```
function [ret-var] = name(arg-list)
  body
end
```

- `arg-list` is a comma-separated list of **input arguments** arg1, arg2, ..., argn
- `ret-var` is a comma-separated list of **output arguments**. Note that `ret-var` is a vector enclosed in square brackets [arg1, arg2, ..., argm].

Functions and Scripts

Example Functions:

```
function [mu sigma] = calcmoments(data)
  mu = mean(data);
  sigma = std(data);
end

function [haspeaks i] = findfirstpeak(data, thresh)
  indices = find(data > thresh);
  if isempty(indices),
    haspeaks = 0; i = [];
  else
    haspeaks = 1; i = indices(1);
  end
end
```

Functions and Scripts

Local Variables, Variable Number of Arguments

- Of course, all variables defined within the body of the function are **local variables**.

- `varargin` Collects all input argument in a cell array. Get them with varargin{i}
- `varargout` Collects all output argument in a cell array. Get them with varargout{i}
- `nargin` Get the number of input args.
- `nargout` Get the number of output args.

See `help varargin`, `help varargout` for details.

Functions and Scripts

Functions and their m-File

- When putting a function into its m-file, the **name of that file** must be the same as the **function name plus the .m extension**.
  Examples: `calcmoments.m, findfirstpeak.m`

- To call a function, type its name **without the .m extension**. Example:
  ```
  [bool i] = findfirstpeak(myreadings, 0.3);
  ```

- **Comments** in Octave/Matlab start with `%` . Make use of them!

Functions and Scripts

Scripts

- The second type of m-files is called script. Again, Octave/Matlab scripts are **text files** with an **.m extension**.
- **Scripts** contain executable code. They are basically the "main" programs.
- Execute a script by typing its name **without the .m extension!**
  Example: `octave:1> LocalizeRobot`
- **Comments** in Octave/Matlab start with `%` .
  (I can't repeat this often enough ;-)

Functions and Scripts

Document your Function/Script

- You can **add a help text to your own functions or scripts** that appears upon `help command`.
- **The first block of comment lines** in the beginning of an m-file is defined to be help text. Example:

```
%NORMANGLE Put angle into a two-pi interval.
%   AN = NORMANGLE(A,MIN) puts angle A into the interval
%   [MIN..MIN+2*pi[. If A is Inf, Inf is returned.

% v.1.0, Dec. 2003, Kai Arras.

function an = normangle(a,mina);
if a < Inf,
[...]
```

help text

Functions and Scripts

Setting Paths

- `path` — Print search path list
- `addpath('dir')` — Prepend the specified directory to the path list
- `rmpath('dir')` — Remove the specified directory from the path list
- `savepath` — Save the current path list

Contents

Files I/O

Save Variables

After a complex of lengthy computation, it is recommended to save variables on the disk.

- `save my_vars.mat`

Saves all current variables into file my_vars.mat

- `save results.mat resultdata X Y`

Saves variables resultdata, X and Y in file results.mat

- `save ... -ascii`

Saves variables in ASCII format

- `save ... -mat`

Saves variables in binary MAT format

Files I/O

Load Variables

The corresponding command is load.

- `load my_vars.mat`

Retrieves all variables from the file my_vars.mat

- `load results.mat X Y`

Retrieves only X and Y from the file results.mat

An ASCII file that contains **numbers in a matrix format** (columns separated by spaces, rows separated by new lines), can be simply read in by

- `A = load('data.txt')`

Files I/O

Open, Write, Close Files

- `fopen` Open or create file for writing/reading
- `fclose` Close file
- `fprintf` Write formatted data to file. C/C++ format syntax.

Example:

```
v = randn(1000,1);
fid = fopen('gauss.txt','w');
for i = 1:length(v),
  fprintf(fid,'%7.4f\n',v(i));
end
fclose(fid);
```

Files I/O

Attention, Popular Bug

- If your program writes to and reads from files, **floating point precision of fprintf** is crucial!
- Be sure to always write floating point numbers into files using the **appropriate precision.**
- In the above example, with `'%7.4f\n'` as the format definition, this file is going to be poor source of Gaussian random numbers.

Files I/O

Reading Files (more advanced stuff)

- `textread` Read formatted data from text file
- `fscanf` Read formatted data from text file
- `fgetl` Read line from file
- `fread` Read binary data file

Read/write images

- `imread` Read image from file (many formats)
- `imwrite` Write image to file (many formats)

Contents

Misc

Cleaning Up

- `clear A` — Clear variable A
- `clear frame*` — Clear all variables whose names start with frame...
- `clear` — Clear **all** variables
- `clear all` — Clear everything: variables, globals, functions, links, etc.

- `close` — Close foreground figure window
- `close all` — Close all open figure windows

- `clc` — Clear command window (shell)

Misc

Displaying (Pretty) Messages

- `disp(A)` Display matrix A without printing the matrix name
- `disp(str)` Display string str without printing the string name

Example: when typing

```
octave:1> disp('done')
```

Octave will respond with

```
done
```

instead of

```
ans = done
```

from `sprintf('done')` or simply `'done'`.

Misc

Command History

- Navigate **up and down** the command history using the up/down **arrow keys**.
- The command history is **start-letter sensitive**. Type one or more letters and use the arrow keys to navigate up and down the history of commands that **start with the letters you typed**.

Tab completion

- Octave/Matlab have tab completion. Type some letters followed by **tab** to get a list of all commands that **start with the letters you typed**.

Misc

Built-in Unix Commands

- `pwd` Display current working directory
- `ls` List directory. See also `dir` .
- `cd` Change directory
- `mkdir` Make new directory
- `rmdir` Delete directory

Related Commands

- `movefile` Move file
- `copyfile` Copy file

Misc

Random Seeds

- `rand` and `randn` obtain their initial seeds from the system clock.
- To generate identical/repeatable sequences, set the random generator seeds manually.

To set the random seeds:

- `rand('seed',value)` Set seed to scalar integer value `value`.
- `randn('seed',value)` Set seed to scalar integer value `value`.

Contents

Octave/Matlab in Practice

Useful Stuff in Practice

- **Generating output** from a C/C++/Python/ Java/... program in Octave syntax
- Making **animations**
- Calling **unix/dos functions** from within Octave programs
- Increasing **speed**

Octave/Matlab in Practice

Output Files in Octave Syntax

- **Data** written in a **matrix format**. Example:

`filtered_readings.txt`

```
0.792258   0.325823   0.957683   0.647680   0.498282
0.328679   0.414615   0.270472   0.975753   0.043852
0.601800   0.062914   0.837494   0.621332   0.870605
0.940364   0.036513   0.843801   0.806506   0.804710
0.937506   0.872248   0.134889   0.042745   0.228380
```

- **Read in** using the command `load`.
  Example: `A = load('filtered_readings.txt');`

Octave/Matlab in Practice

Output Files in Octave Syntax

- File contains **code snippets**. Example:

`PlotFilteredReadings.m`

```
A = [
0.792258   0.325823   0.957683   0.647680   0.498282
0.328679   0.414615   0.270472   0.975753   0.043852
0.601800   0.062914   0.837494   0.621332   0.870605
0.940364   0.036513   0.843801   0.806506   0.804710
];
figure(1); clf; hold on;
plot(1:size(A,1),A(:,1));
```

- Must have the **.m extension**. It's a script.
- Simply **execute** by typing `PlotFilteredReadings`

Octave/Matlab in Practice

Making Animations

- **Matlab** has commands such as `getframe` and `movie` to make animated movies from plots.
- **Octave**, being free of charge, does not (yet) support these commands.
- Never mind! Here is a pretty obvious way to **make movies:**

  Export plots to a "frames" directory using `print` from within a **loop**. Then compose frames to a movie using tools such as ImageMagick or Quicktime Pro.

Octave/Matlab in Practice

Making Animations. Example:

- Let `data.txt` contain data in matrix format, we want to plot each column and save it as a frame.

```
A = load('data.txt');
[m n] = size(A);
figure(1);
for i = 1:n,
  plot(1:m,A(:,i));
  fname = sprintf('frames/frame%04d.png',i);
  print('-dpng','-r100',fname);
end
```

- **Problem: axis limits change** for each plot/frame.

Octave/Matlab in Practice

Making Animations. Example:

- To **freeze the axes** over the entire animation, use the command `axis([xmin xmax ymin ymax])` **after** the plot command.

```
A = load('data.txt');
[m n] = size(A);
figure(1);
for i = 1:n,
  plot(1:m,A(:,i));
  axis([1 m min(min(A)) max(max(A))]);
  fname = sprintf('frames/frame%04d.png',i);
  print('-dpng','-r100',fname);
end
```

Octave/Matlab in Practice

Calling unix/dos Functions

- For Unix/Linux/MacOSX systems, there is the command `unix` to execute system commands and return the result. Examples:

```
unix('ls -al')
unix('ftp < ftp_script')
unix('./myprogram')
```

- For PCs, there is the equivalent command `dos` .

- These commands allow for **powerful and handy combinations** with other programs or system commands.

Octave/Matlab in Practice

Speed!

- The **lack of speed** of Octave/Matlab programs is widely recognized to be their biggest drawback.
- Mostly it's **your program that is slow**, not the built-in functions!
- This brings us to the following **guidelines**:
  - **For-loops** are **evil**
  - **Vectorization** is **good**
  - **Preallocation** is **good**
  - Prefer **struct of arrays** over arrays of struct

Octave/Matlab in Practice

Speed: Vectorization

- Given `phi = linspace(0,2*pi,100000);`

  The code

```
for i = 1:length(phi),
  sinphi(i) = sin(phi(i));
end;
```

  is significantly slower than simply

```
sinphi = sin(phi);
```

- Nearly **all built-in commands** are **vectorized**. Think vectorized!

Octave/Matlab in Practice

Speed: Preallocation

- If a for- or while-loop cannot be avoided, do not grow data structures in the loop, **preallocate them** if you can. Instead of, e.g.,

```
for i = 1:100,
  A(i,:) = rand(1,50);
end;
```

Write:

```
A = zeros(100,50);   % preallocate matrix
for i = 1:100,
  A(i,:) = rand(1,50);
end;
```

Octave/Matlab in Practice

Speed: Structure of Arrays

- Always prefer a struct of arrays over a array of structs. It requires **significantly less memory** and has a corresponding **speed benefit**.
- Structure of arrays

```
data.x = linspace(0,2*pi,100);
data.y = sin(data.x);
```

- Array of structure

```
people(1).name = 'Polly J Harvey';
people(1).age = 32;

people(2).name = 'Monica Lebowski';
people(2).age = 27;
```

Contents

librobotics

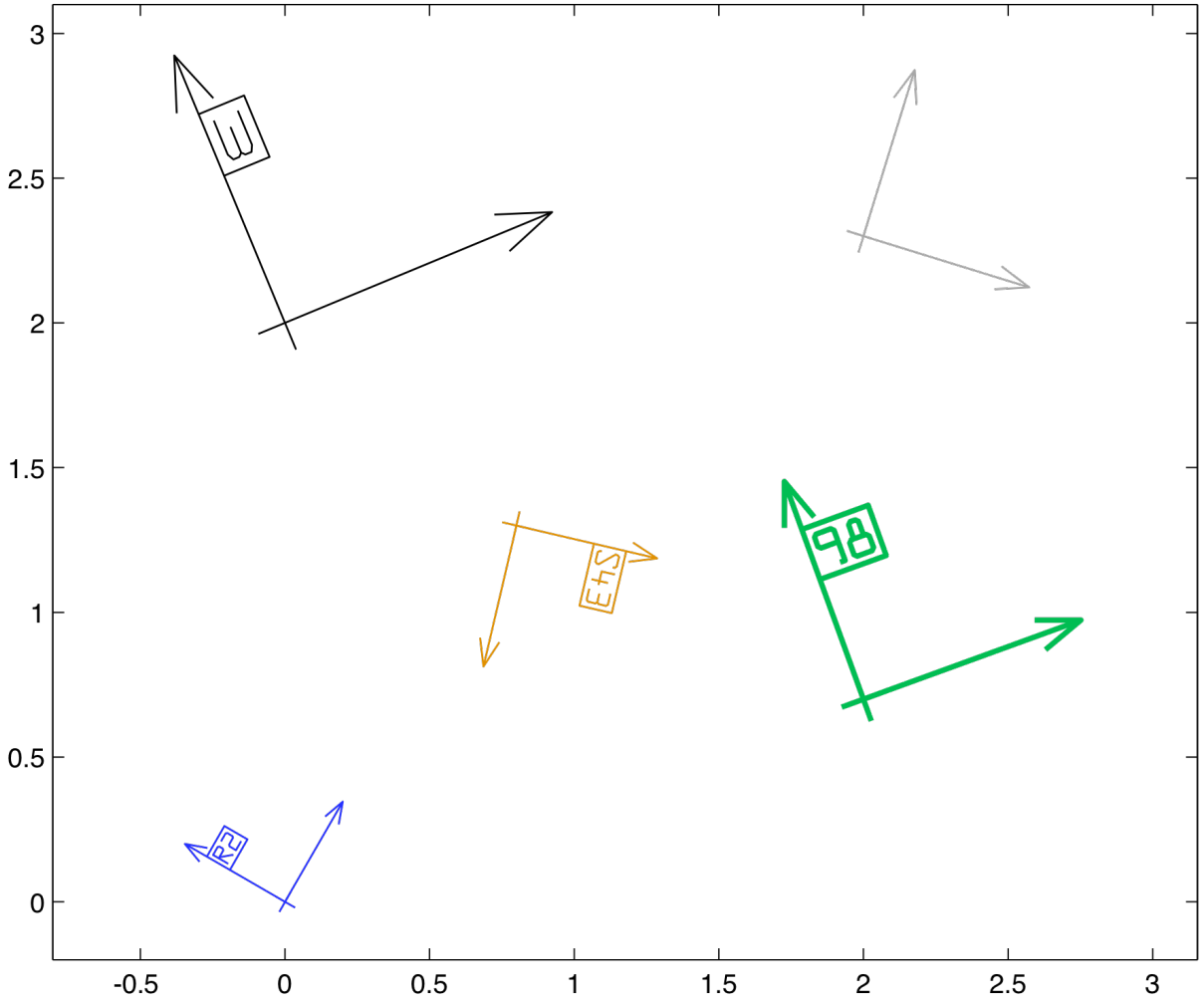
- **librobotics** is a small library with frequently used Octave/Matlab functions in Robotics, especially for visualization.

```
chi2invtable.m      drawrawdata.m       j2comp.m
compound.m          drawreference.m     jinv.m
diffangle.m         drawrobot.m         mahalanobis.m
drawarrow.m         drawrect.m          meanwm.m
drawellipse.m       drawtransform.m     normangle.m
drawlabel.m         icompound.m
drawprobellipse.m   j1comp.m
```

- **Download** from SRL Homepage: srl.informatik.uni-freiburg.de/downloads

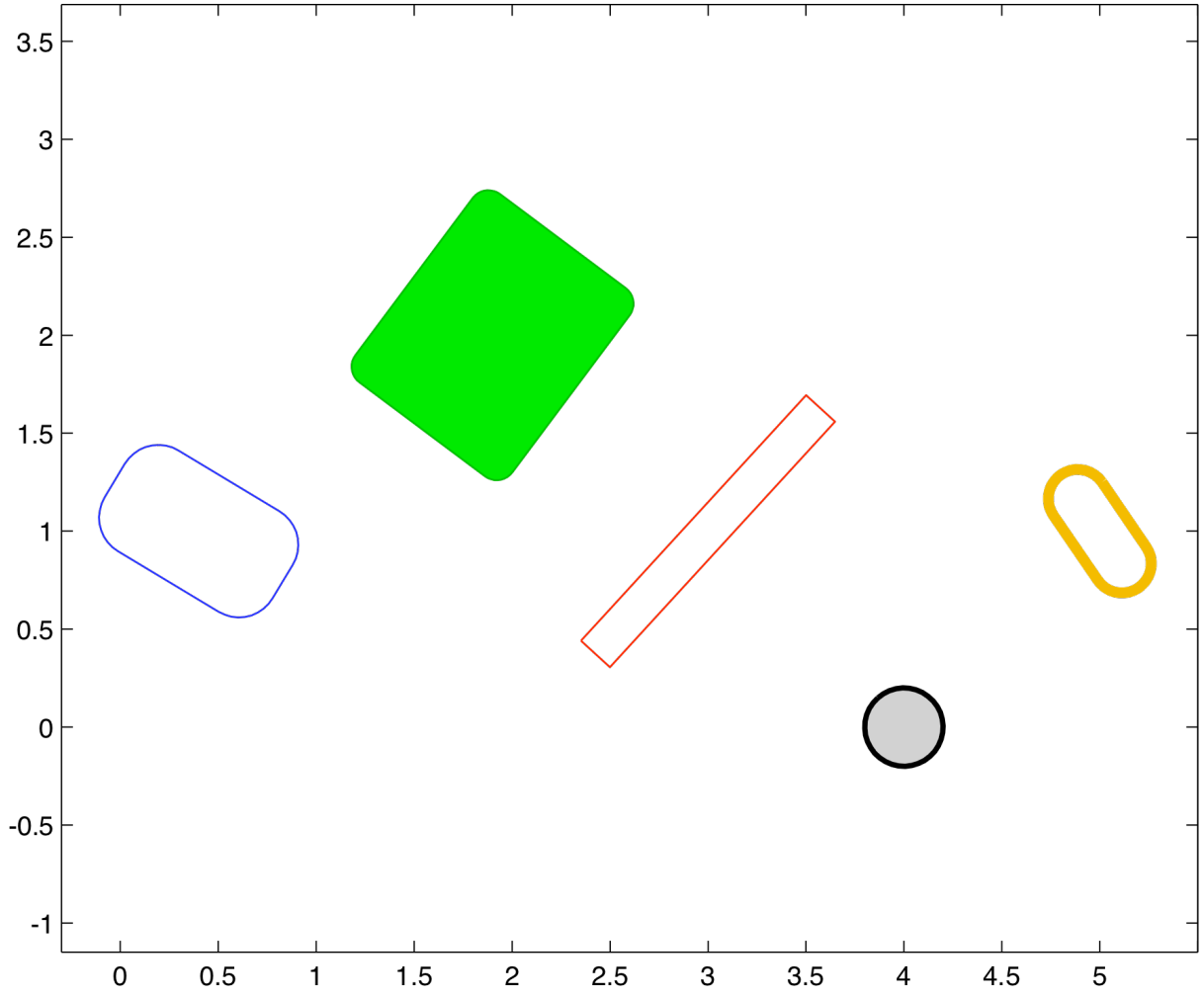
librobotics

Command `drawreference.m`



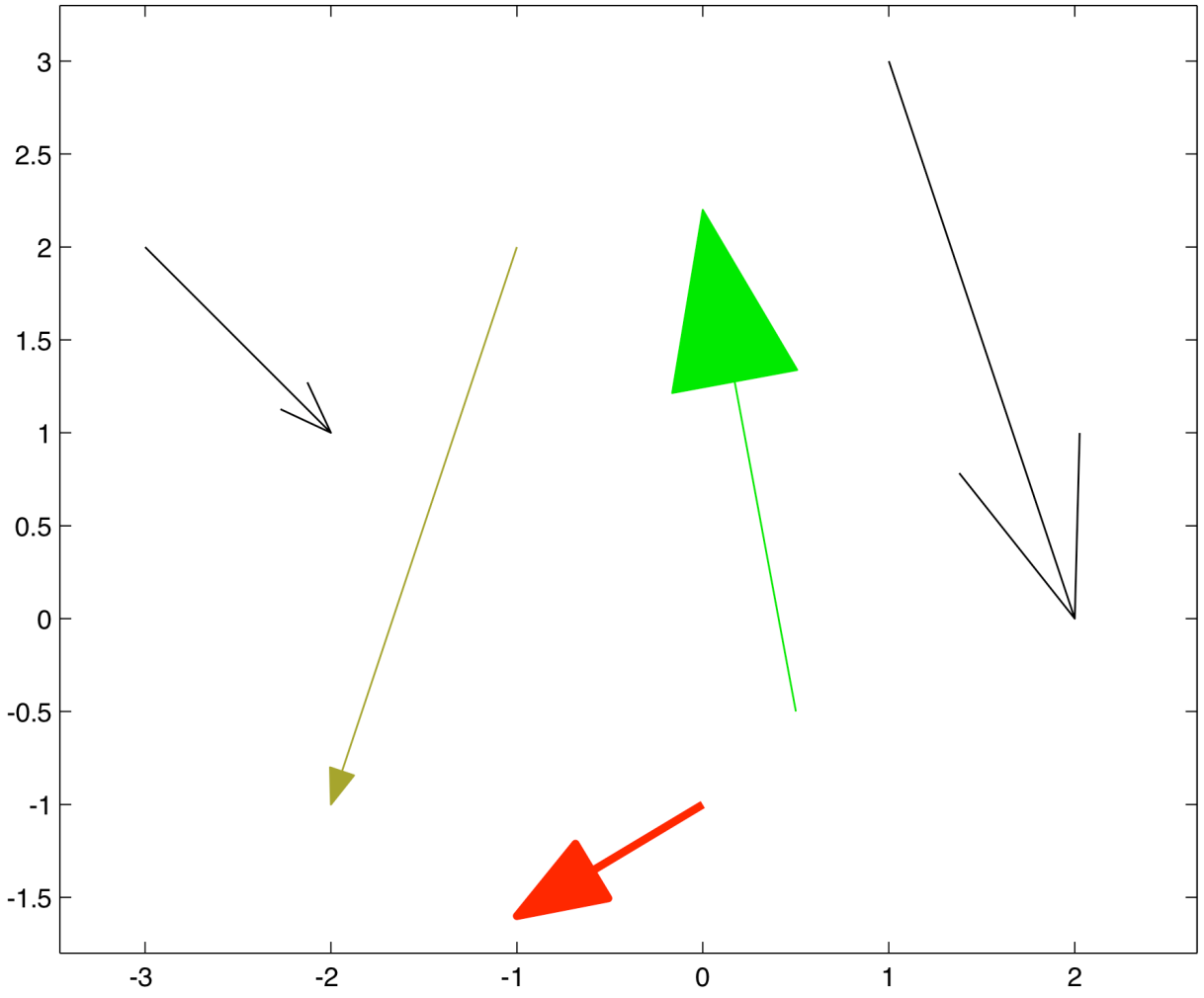
librobotics

Command `drawrect.m`



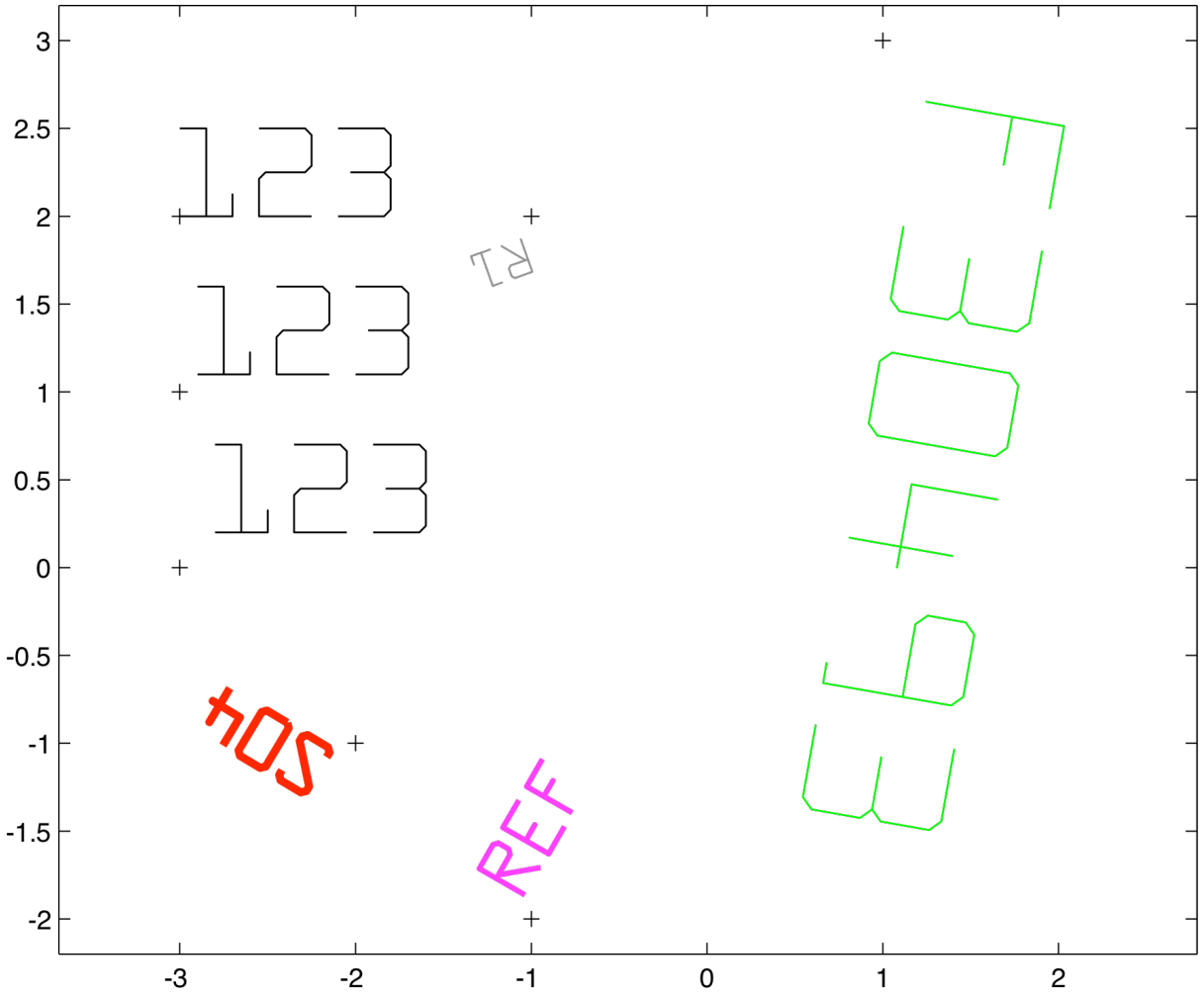
librobotics

Command `drawarrow.m`



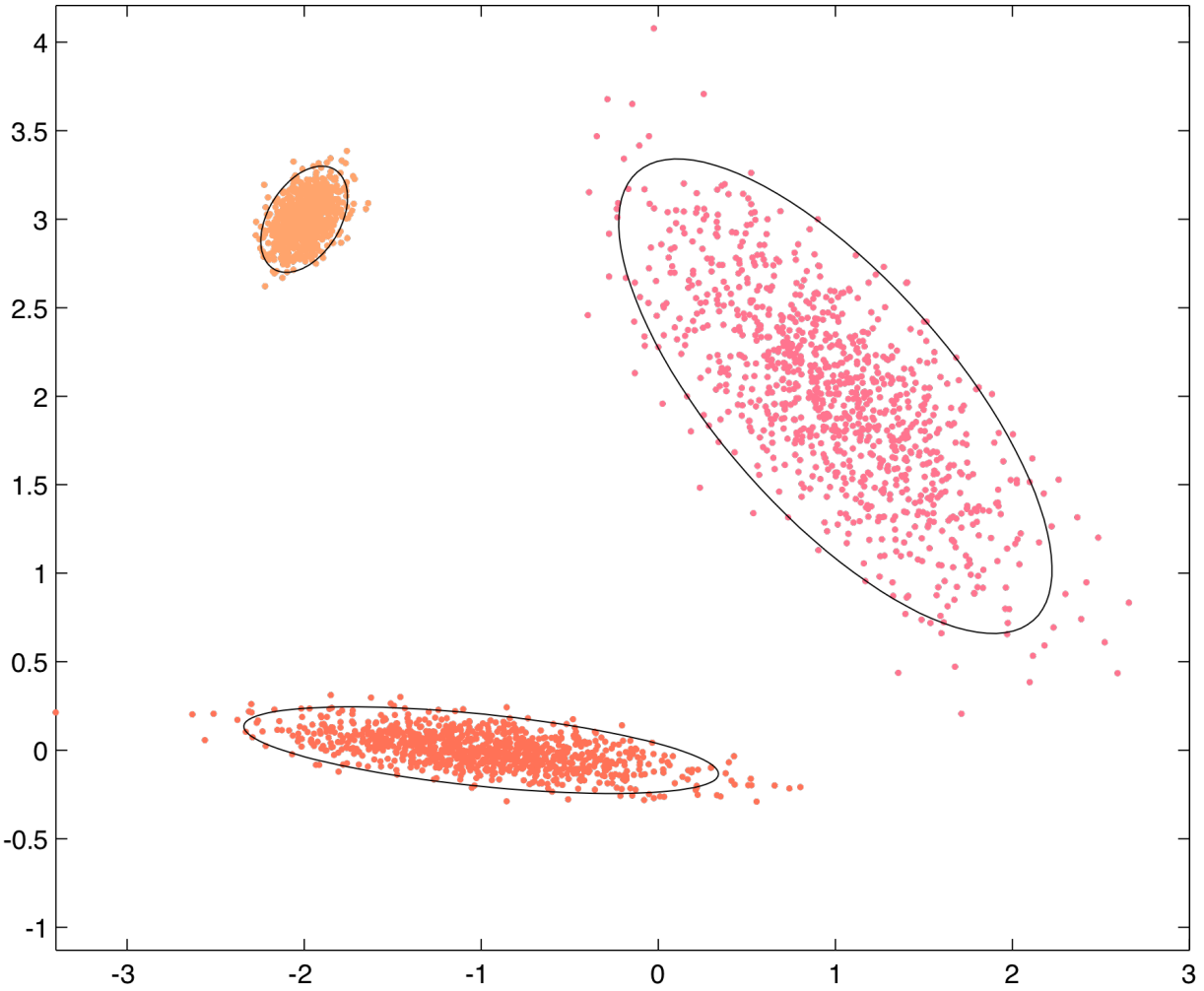
librobotics

Command `drawlabel.m`



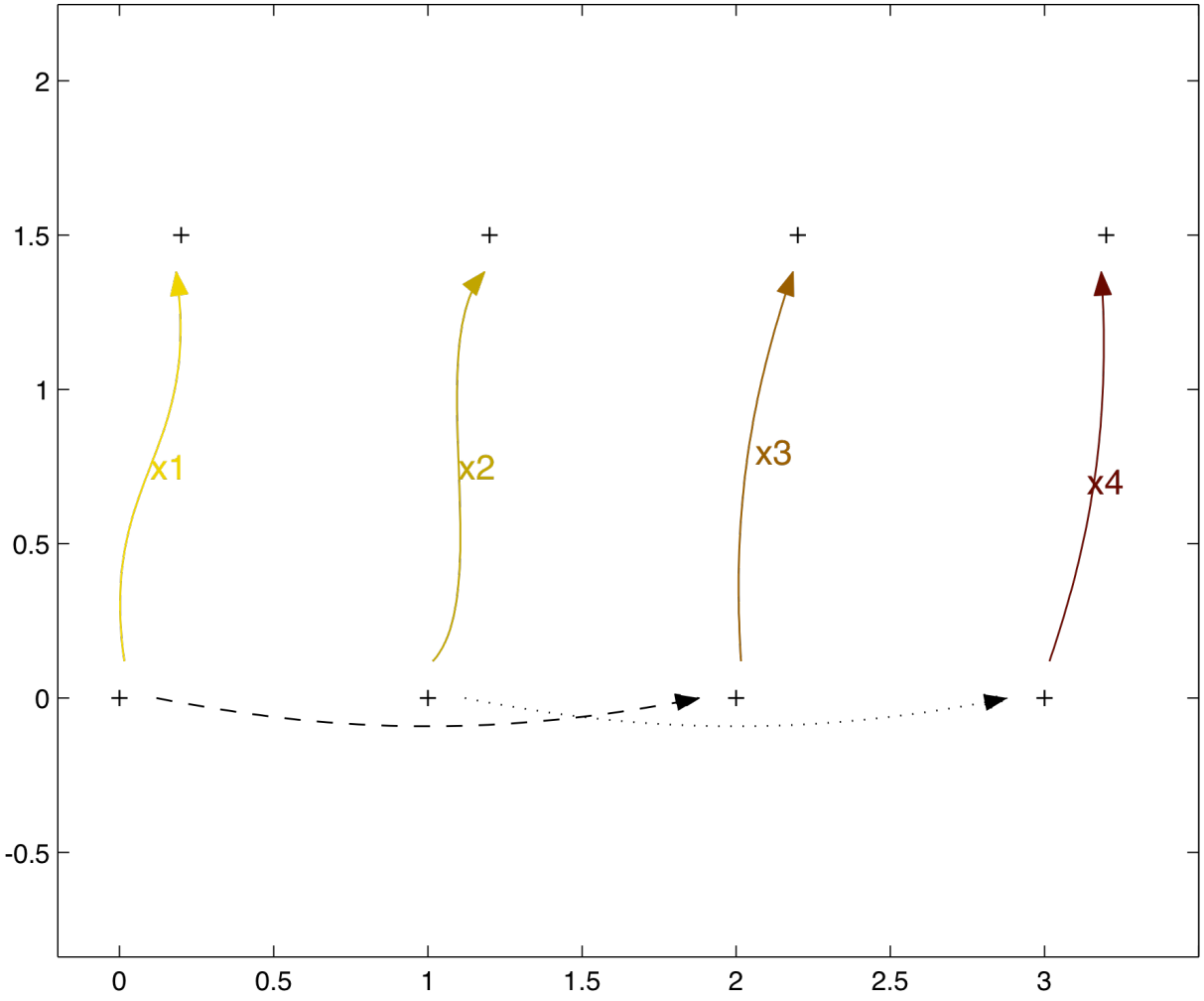
librobotics

Command `drawprobellipse.m`



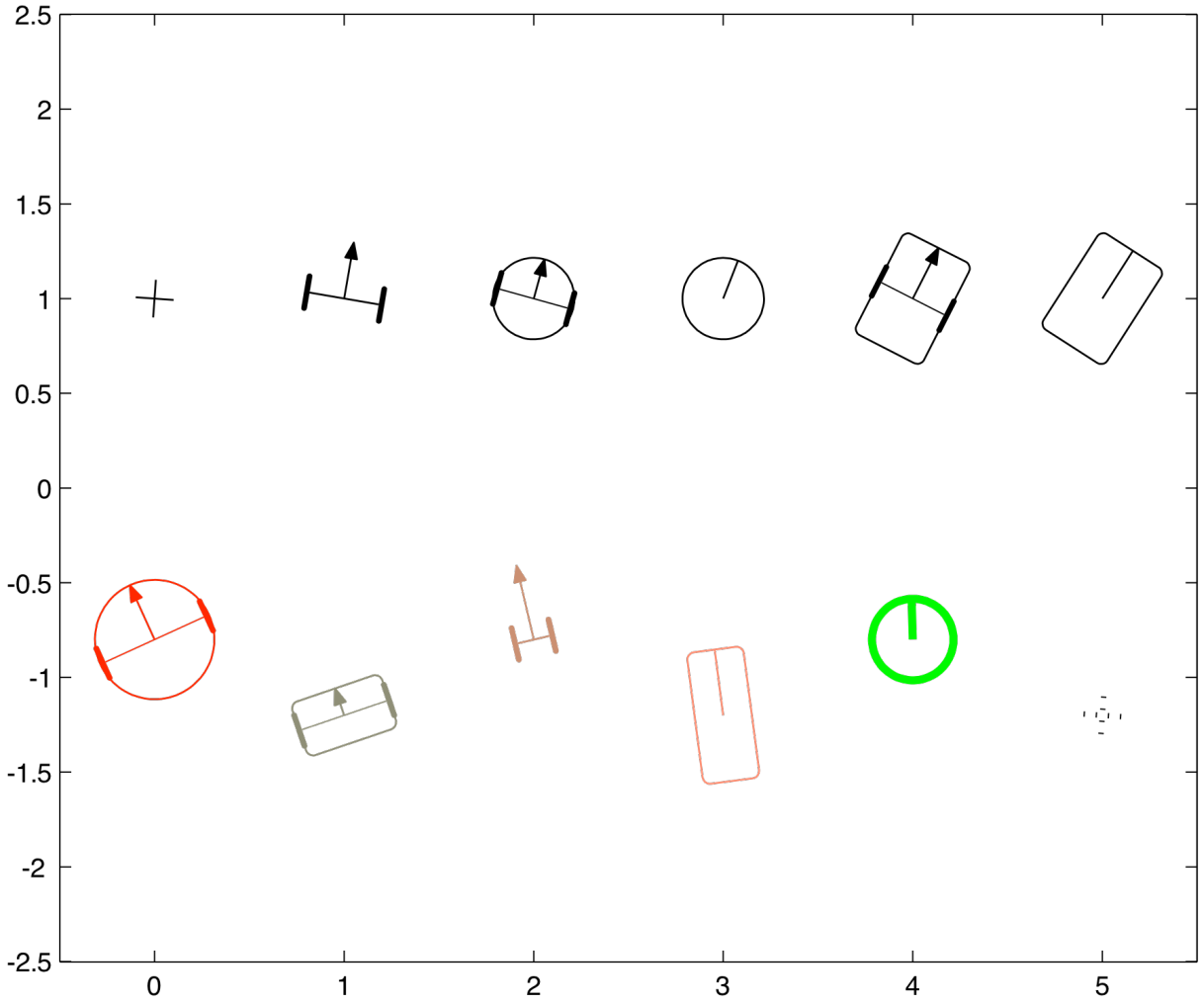
librobotics

Command `drawtransform.m`



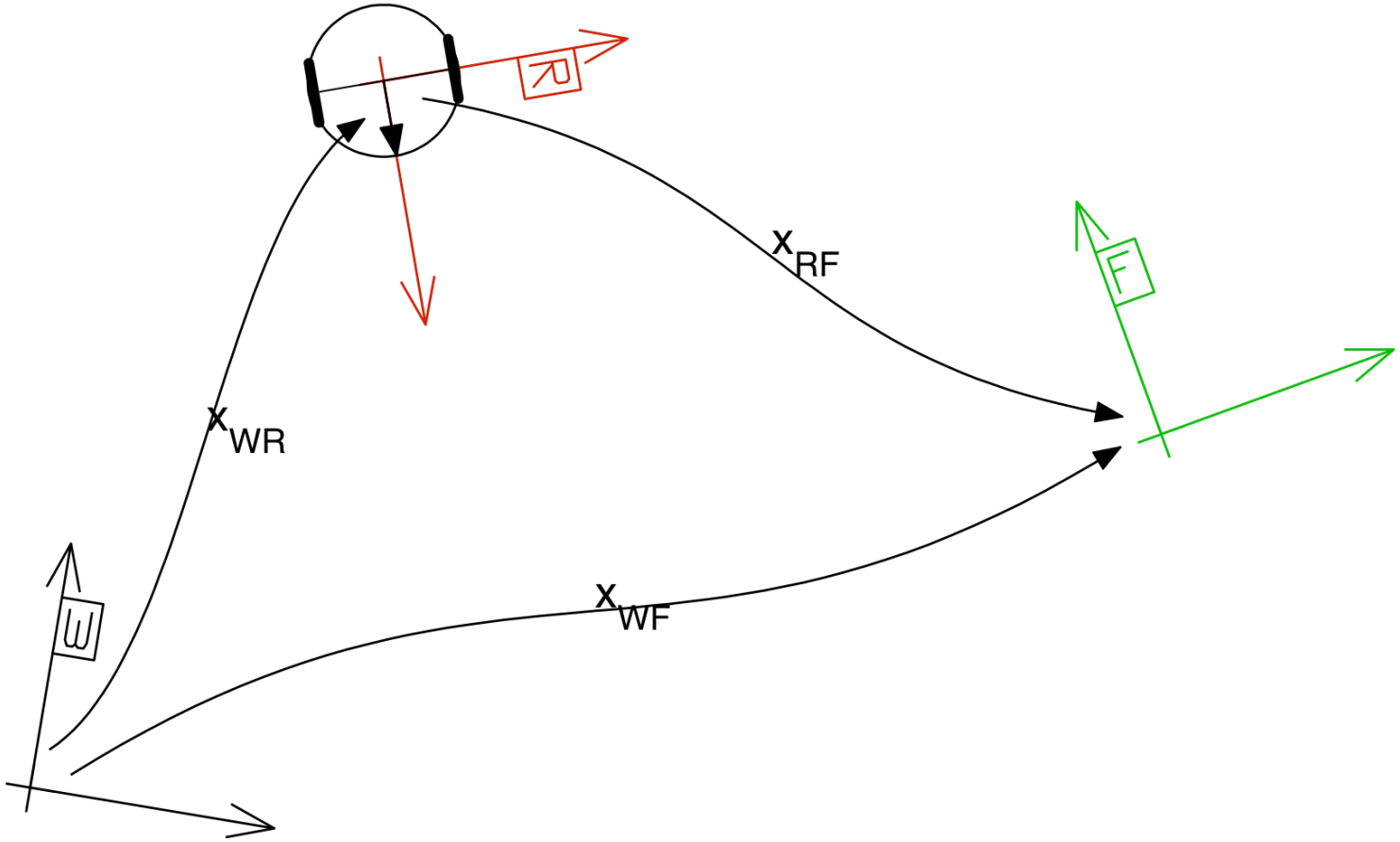
librobotics

Command `drawrobot.m`



librobotics

Example Figure



librobotics

- All commands are **fully documented**, just type `help command`.
- Note the command `chi2invtable.m`. It returns values of the **cumulative chi square distribution**, typically used for gating and hypothesis testing. It replaces the `chi2inv` function from the Matlab statistics toolbox (which is a costly addition to Matlab) while being much faster, too.
- librobotics is **compatible with both, Matlab** and **Octave.**
- It's **open source**, feel free to distribute and extend.

More Information

Full Octave online documentation:

http://www.octave.org

- ➛ Docs
- ➛ 575 page manual

(directly: www.gnu.org/software/octave/doc/interpreter)

Full Matlab online documentation:

http://www.mathworks.com

- ➛ Products & Services
- ➛ Product List
- ➛ MATLAB
- ➛ Documentation

Thanks and Enjoy!

Kai Arras

Social Robotics Lab