# Lecture 2
# Advanced MATLAB: Graphics

Matthew J. Zahr

**CME 292**
Advanced MATLAB for Scientific Computing
Stanford University

7th April 2015

# Announcements

- Office hours are set for 5p - 7p in Durand 028 (or by drop-in/appointment)
- Homework 1 out today, due next Tuesday (4/14)

# Outline



# Overview

- Graphics objects
  - Basic drawing elements used by MATLAB to display data
  - Each object *instance* has unique identifier, *handle*
    - Stored as a double
  - Objects organized in *hierarchy*

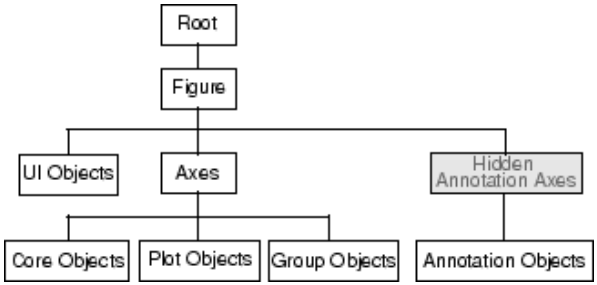



Figure: Organization of Graphics Objects (MathWorks `http://www.mathworks.com/help/matlab/creating_plots/organization-of-graphics-objects.html`)

# Graphics Objects

Two basic types of graphics objects

- Core graphics object
  - `axes`, `image`, `light`, `line`, `patch`, `rectangle`, `surface`, `patch`
- Composite graphics object
  - Plot objects
    - `areaseries`, `barseries`, `contourgroup`, `errorbarseries`, `lineseries`, `quivergroup`, `scattergroup`, `staircase`, `stemseries`, `surfaceplot`
  - Annotation objects
    - arrow, doublearrow, ellipse, line, rectangle, textarrow, textbox
  - Group objects
    - `hggroup`, `hgtransform`
  - User Interface objects

# Graphics Handle

- Similar to *pointers* in that they contain a *reference* to a particular graphics object
  - `h1 = figure(2); h2 = h1;`
  - Both `h1`, `h2` point to figure 2
- Best way to obtain graphics handle is *from the call that creates the graphics object*, i.e.
  - `figH = figure('pos',[141,258,869,523]);`
  - `axH = axes();`
  - `ax1H = subplot(2,2,3);`
  - `sinH = plot(sin(linspace(0,2*pi,100)))`
  - `[c,contH] = contour(peaks);`
- Alternatively, obtain graphics handle manually
  - Select figure/axes/object of interest with mouse
  - Use `gcf`, `gca`, `gco`
- Graphics handles stored as `double`

# Handle stored as `double`

The value of the `double` really is the *only* identifier of the graphics object

```
>> format long
>> ax1 = gca % Copy/paste output to ax2
>> ax2 = 1.197609619140625e+03
>> ishandle(ax2)
ans =
     1
```

# Specifying Figure or Axes to Use

Handles can be used to specify which figure or axes is used when new graphics objects generated

- Specify figure in which to create new axes object
  - `for i = 1:10, fHan(i)=figure(); end`
  - `ax = axes('Parent',fHan(4))`
- Specify axes in which to create new graphics object
  - Most, if not all, plotting commands accept an axes handle as the *first* argument
  - Graphics object generated in axes object corresponding to handle passed
  - If axes handle not specified, `gca` used
  - `[C,objHan] = contourf(ax,peaks)`
- By default, MATLAB uses `gcf` (handle of current figure) or `gca` (handle of current axes)

# Exercise

- You are provided a fairly useless piece of code below (`which_plot_ex.m`)
- Your task is to alter the code below such that
  - `sin(k*x)` is plotted vs `x` for `k` even in a single figure
  - `sin(k*x)` is plotted vs `x` for `k` odd in a single figure (different figure from the one above)

```
figure;
axes(); hold on;

figure;
axes(); hold on;

x = linspace(0,2*pi,1000);
for k = 1:10
    plot(x,sin(k*x));
end
```

# Working with Graphics Objects

| Command | Description |
|---|---|
| `gca` | Return handle of current axes |
| `gcf` | Return handle of current figure |
| `gco` | Return handle of current object |
| `get` | Query values of object's properties |
| `ishandle` | True if value is valid object handle |
| `set` | Set values of an object's properties |

# Working with Graphics Objects

| Command | Description |
|---|---|
| `allchild` | Return all children of objects |
| `ancestor` | Return ancestor of object |
| `copyobj` | Copy graphics object |
| `delete` | Delete an object |
| `findall` | Return all graphics objects |
| `findobj` | Return handles of objects with specified property |

# Query/Modify Graphics Object Properties

- `get` to query properties and values for any graphics handle
  - `get(han)`
    - Display all properties and values to screen
  - `get(han,'Property')`
    - Display `Property` value to screen
  - `V = get(han)`
    - Store all properties-value pairs in structure `V`
  - `V = get(han,'Property')`
    - Store `Property` value in `V`
- `set` to set properties for any graphics handle
  - `set(han,'Prop-1',Val-1,'Prop-2',Val-2...)`
    - Set `Prop-j`'s value to `Val-j`
  - `set(han,s)` `%s structure`
    - Set property-value pairs from `s`
  - `set(han,pn,pv)` `%pn, pv cell arrays`
    - Set value of property `pn{i}` to `pv{i}`

# Properties Common to All Objects

| Command | Description |
|---|---|
| `BeingDeleted` | `on` when object's `DeleteFcn` called |
| `BusyAction` | Control callback routine interruption |
| `ButtonDownFcn` | Callback routine that executes when button pressed |
| `Children` | Handles of all object's child objects |
| `Clipping` | Enables/disables clipping |
| `CreateFcn` | Callback routine that executes when object created |
| `DeleteFcn` | Callback routine that executes when object deleted |

# Properties Common to All Objects

| Command | Description |
|---|---|
| `HandleVisibility` | Allows control over object handle's visibility (command line and callbacks) |
| `HitTest` | Determines if object selectable via mouse click |
| `Interruptible` | Determines whether callback can be interrupted by subsequently called callback |
| `Parent` | The object's parent |
| `Selected` | Indicates whether object is selected |

# Properties Common to All Objects

| Command | Description |
|---|---|
| `SelectionHighlight` | Specifies whether object visually indicates selection state |
| `Tag` | User-specified object label |
| `Type` | The type of object |
| `UserData` | Any data user associates with object |
| `Visible` | Determines whether object is visible |

# Figure, Axes, and Plot Objects

- Figure window
  - `get(gcf)` to see all properties of Figure object and defaults
  - `Colormap`, `Position`, `PaperPositionMode`
- Axes Object
  - Axes objects contain the lines, surfaces, and other objects that represent the data visualized in a graph
  - `get(gca)` to see all properties of Figure object and defaults
  - `XLim`, `YLim`, `ZLim`, `CLim`, `XGrid`, `YGrid`, `ZGrid`, `XTick`, `XTickLabel`, `YTick`, `YTickLabel`, `ZTick`, `ZTickLabel`, `XScale`, `YScale`, `ZScale`
- Plot Objects
  - Plot objects are composite graphics objects composed of one or more core objects in a group
  - `XData`, `YData`, `ZData`, `Color`, `LineStyle`, `LineWidth`

# The Figure Window

- `get(gcf)` to see all properties of Figure object and defaults
  - `Colormap`
    - Defines colors used for plots
    - Must be $m \times 3$ array of $m$ RGB values
  - `PaperOrientation`, `PaperPosition`, `PaperPositionMode`, `PaperSize`
    - Relevant for printing
  - `Position`
    - Position and size figure: `[x, y, w, h]`
    - `x`, `y` - $(x, y)$ coordinates of lower left corner of figure
    - `w`, `h` - width, height of figure
  - `NextPlot`
    - Behavior when multiple axes object added to figure

# The Axes Object

Axes objects contain the lines, surfaces, and other objects that represent the data visualized in a graph

- `get(gca)` to see all properties of Axes object and defaults
  - `XLim`, `YLim`, `ZLim`, `CLim`
    - Set plot limits in each dimension (including color)
    - More information on `CLim` here
  - `XGrid`, `XMinorGrid`, `YGrid`, `YMinorGrid`, `ZGrid`, `ZMinorGrid`
    - Toggle major and minor grid lines in each dimension
  - `XTick`, `XTickLabel`, `YTick`, `YTickLabel`, `ZTick`, `ZTickLabel`
    - Control tick locations and labels in each dimension
  - `XScale`, `YScale`, `ZScale`
    - Toggle between linear and log scale in each dimension
  - Camera, Fonts, Line style options

# Colormap

Colormaps enable control over how MATLAB maps data values to colors in surfaces, patches, images, and plotting functions

- `C = colormap(jet(128));`
  - Sets colormap of current figure to `jet` with `128` colors
  - `autumn`, `bone`, `colorcube`, `cool`, `copper`, `flag`, `gray`, `hot`, `hsv`, `jet`, `lines`, `pink`, `prism`, `spring`, `summer`, `white`, `winter`
- Alternatively

```
>> fig = figure();
>> ax = axes('Parent',fig);
>> load spine; image(X);
>> colormap(ax,bone);
```

  - This is a bit strange as `Colormap` is a property of the figure (not axes), but the axes handle is passed to `colormap`
    - Access to figure handle (`get(ax,'Parent')`)

# Plot Objects

- Plot objects are composite graphics objects composed of one or more core objects in a group
- Most common plot objects: `lineseries`, `contourgroup`
- `Lineseries`
  - `XData`, `YData`, `ZData`
    - Control $x, y, z$ data used to plot line
  - `Color`, `LineStyle`, `LineWidth`
    - Control appearance of line
  - `Marker`, `MarkerSize`, `MarkerEdgeColor`, `MarkerFaceColor`
    - Control appearance of markers on line
- `Contourgroup`
  - `XData`, `YData`, `ZData`
    - Control $x, y, z$ data used to plot line
  - `LineStyle`, `LineWidth`, `LineColor`
  - `Fill`, `LevelStep`

# Legend

- Probably familiar with basic legend syntax
  - `legend('First plotted','Second ... plotted','Location','Northwest')`
- What if legend based on order of objects plotted is not sufficient?
  - Use handles for fine grained control
  - `legend(h,'h(1)label','h(2)label')`
- Legend handle
  - Get handle by `leg = legend( )`
  - Use handle to control size/location (more control than `'Location'`)
  - Font size/style, interpreter, line style, etc

# Callback Routines

- Function associated with graphics handle that gets called in response to a specific action applied to the associated graphics object
  - Object creation, deletion
  - Mouse motion, mouse press, mouse release, scroll wheel
  - Key press, key release
  - More here
- All callback routines automatically passed two inputs
  - Handle of component whose callback is being executed
  - Event data
- Callback routines specified in many possible forms
  - String
    - Expression evaluated in *base* workspace
  - Function handle
  - Cell arrays to pass additional arguments to callback routine

# Demo & In-Class Assignment

`graphics_obj_han_ex.m`

# Outline



# Line plots

| Command | Description |
|---|---|
| `plot` | 2D line plot |
| `plotyy` | 2D line plot, y-axes both sides |
| `plot3` | 3D line plot |
| `loglog` | 2D line plot: x- and y-axis log scale |
| `semilogx` | 2D line plot, x-axis log, y-axis linear |
| `semilogy` | 2D line plot, x-axis linear, y-axis log |
| `errorbar` | Error bars along 2D line plot |
| `fplot` | Plot function between specified limits |
| `ezplot` | Function plotter |
| `ezplot3` | 2D parametric curve plotter |

# Examples: `plotyy`, `errorbar`

Figure: `plotyy` Plot

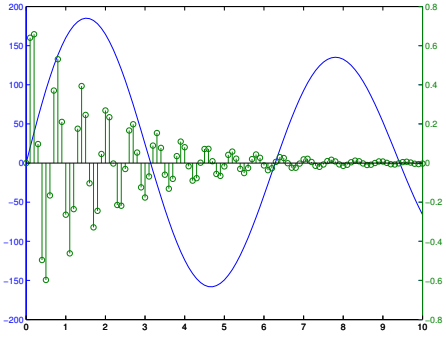
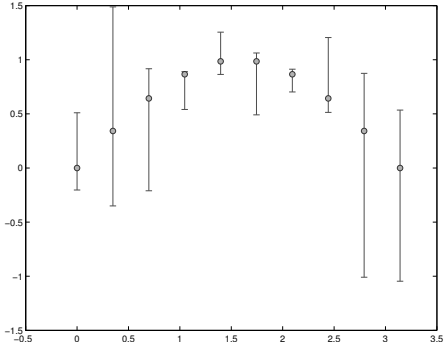



Figure: `errorbar` Plot




- Code: `advanced_plotting_ex.m`

# Line plots: Examples

- Multiple y-axes
  - `[ax,h1,h2]=plotyy(X1,Y1,X2,Y2)`
    - Plot `X1`, `Y1` using left axis and `X2`, `Y2` using right axis
  - `[ax,h1,h2]=plotyy(X1,Y1,X2,Y2,'function')`
    - Plot `X1`, `Y1` using left axis and `X2`, `Y2` using right axis with plotting function defined by string `'function'`
  - `[ax,h1,h2]=plotyy(X1,Y1,X2,Y2,'f1','f2')`
    - Plot `X1`, `Y1` using left axis with plotting function `'f1'` and `X2`, `Y2` using right axis with plotting function `'f2'`
- Error plots
  - `h = errorbar(X,Y,E)`
    - Create 2D line plot from data `X`, `Y` with symmetric error bars defined by `E`
  - `h = errorbar(X,Y,L,U)`
    - Create 2D line plot from data `X`, `Y` with upper error bar defined by `U` and lower error bar defined by `L`

# Pie Charts, Bar Plots, and Histograms

| Command | Description |
|---|---|
| `bar`, `barh` | Vertical, horizontal bar graph |
| `bar3`, `bar3h` | Vertical, horizontal 3D bar graph |
| `hist` | Histogram |
| `histc` | Histogram bin count (no plot) |
| `rose` | Angle histogram |
| `pareto` | Pareto chart |
| `area` | Filled area 2D plot |
| `pie`, `pie3` | 2D, 3D pie chart |

# Examples: `hist`, `bar`, `barh`, `pie3`

Figure: `hist/bar/barh` Plot

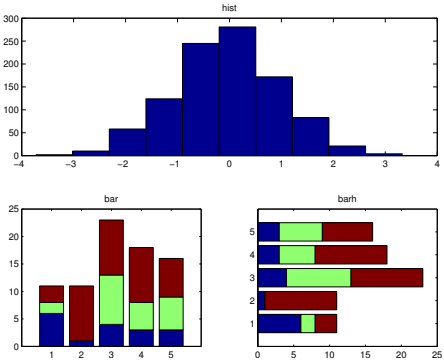
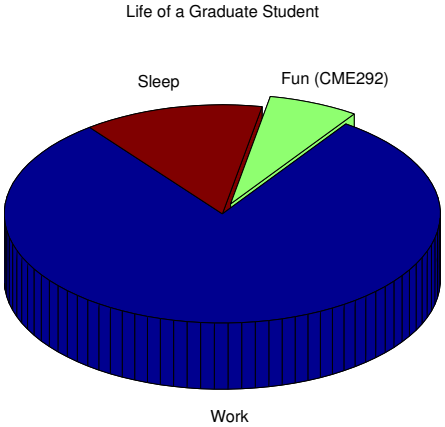



Figure: `pie3` Plot




- Code: `advanced_plotting_ex.m`

# Discrete Data Plots

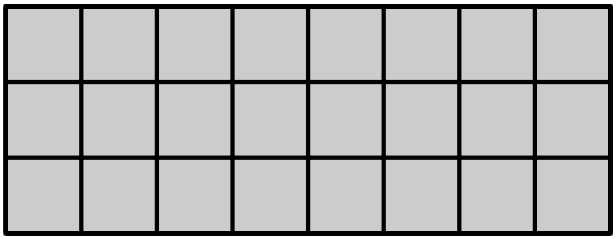
| Command | Description |
|---|---|
| `stem`, `stem3` | Plot 2D, 3D discrete sequence data |
| `stair` | Stairstep graph |
| `scatter`, `scatter3` | 2D, 3D scatter plot |

# Polar Plots

| Command | Description |
|---|---|
| `polar` | Polar coordinates plot |
| `rose` | Angle histogram plot |
| `compass` | Plot arrows emanating from origin |
| `ezpolar` | Polar coordinate plotter |

# Generating Grid Data

- MATLAB graphics commands work primarily in terms of $N$-D grids



- Use `meshgrid` to define grid compatible with 2D, 3D MATLAB plotting commands from discretization in each dimension
  - `[X,Y] = meshgrid(x,y)`
  - `[X,Y,Z] = meshgrid(x,y,z)`

## meshgrid

- Generate 2D grid: `[X,Y] = meshgrid(x,y)`
  - Relationships
    - `X(i,:)` = `x` for all $i$
    - `Y(:,j)` = `y` for all $j$
    - `X(:,i)` = `x(i)` for all $i$
    - `Y(j,:)` = `y(j)` for all $j$
- Generate 3D grid: `[X,Y,Z] = meshgrid(x,y,z)`
  - Relationships
    - `X(i,:,k)` = `x` for all $i, k$
    - `Y(:,j,k)` = `y` for all $j, k$
    - `Z(i,j,:)` = `z` for all $i, j$
    - `X(:,i,:)` = `x(i)` for all $i$,
    - `Y(j,:,:)` = `y(j)` for all $j$
    - `Z(:,:,k)` = `z(k)` for all $k$

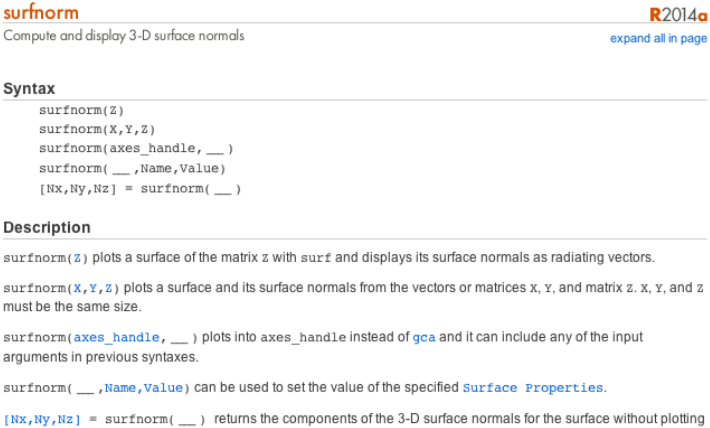
# Implication of `meshgrid` ordering

Consider the implication of `meshgrid` in the context of the function $\mathbf{F}(x, y) = \sin(x)\cos(y)$

- `s = linspace(0,2*pi,100)`
- `[X,Y] = meshgrid(s,s)`
- `F = sin(X).*cos(Y)`
- `F(i,j)== sin(X(i,j))*cos(Y(i,j))`
  `== sin(s(?))*cos(s(?))`
  `== sin(s(j))*cos(s(i))`

# `meshgrid` and Plotting Functions

- In MATLAB Help documentation, grid or domain data inputs/outputs usually refer to output of `meshgrid` or `meshgrid` or `ndgrid`



surfnorm

R2014a

Compute and display 3-D surface normals

expand all in page

**Syntax**

```
surfnorm(Z)
surfnorm(X,Y,Z)
surfnorm(axes_handle, __ )
surfnorm( __ ,Name,Value)
[Nx,Ny,Nz] = surfnorm( __ )
```

**Description**

`surfnorm(Z)` plots a surface of the matrix `Z` with `surf` and displays its surface normals as radiating vectors.

`surfnorm(X,Y,Z)` plots a surface and its surface normals from the vectors or matrices `X`, `Y`, and matrix `Z`. `X`, `Y`, and `Z` must be the same size.

`surfnorm(axes_handle, __ )` plots into `axes_handle` instead of `gca` and it can include any of the input arguments in previous syntaxes.

`surfnorm( __ ,Name,Value)` can be used to set the value of the specified `Surface Properties`.

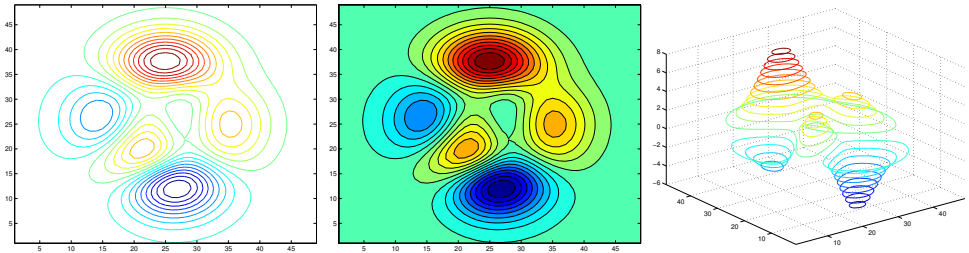
`[Nx,Ny,Nz] = surfnorm( __ )` returns the components of the 3-D surface normals for the surface without plotting the surface or surface normals.

# Contour Plots

- Plot scalar-valued function of two variables as lines of constant value.
  - Visualize $f(x, y) \in \mathbb{R}$ by displaying lines where $f(x, y) = c$ for various values of $c$

| Command | Description |
|---|---|
| `contour` | Contour plot |
| `contourf` | Filled contour plot |
| `contourc` | Contour plot computation (no plot) |
| `contour3` | 3D contour plot |
| `contourslice` | Draw contours in volume slice planes |
| `ezcontour` | Contour plotter |
| `ezcontourf` | Filled contour plotter |

# Contour Plots



(a) `contour` (b) `contourf` (c) `contour3`

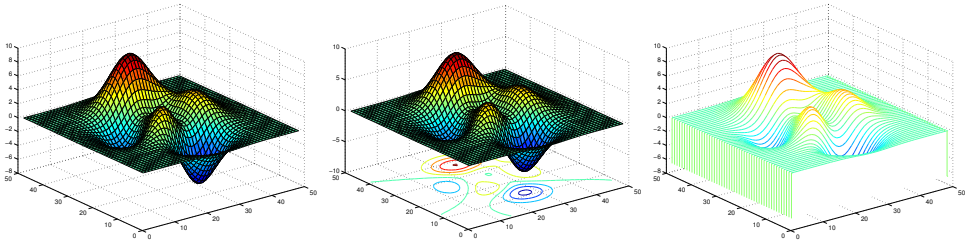
Code for plots generated in the remainder of the section:
`advanced_plotting_ex.m` or `lec_figs.m`

# Surface and Mesh Plots

- Plot scalar-valued function of two variables $f(x, y) \in \mathbb{R}$

| Command | Description |
|---|---|
| `surf` | 3D shaded surface plot |
| `surfc` | Contour plot under `surf` plot |
| `surfl` | Surface plot with colormap lighting |
| `surfnorm` | Compute/plot 3D surface normals |
| `mesh` | Mesh plot |
| `meshc` | Contour plot under `mesh` plot |
| `waterfall` | Waterfall plot |
| `ribbon` | Ribbon plot |
| `ezsurf`, `ezsurfc` | Colored surface plotters |
| `ezmesh`,`ezmeshc` | Mesh plotters |

# Suface/Mesh Plots



(a) `surf` (b) `surfc` (c) `waterfall`

(d) `mesh` (e) `meshc`

# Contour/Surface/Mesh Plots

- `[C,h] = contour_func(Z)`
  - Contour plot of matrix `Z`
- `[C,h] = contour_func(Z,n)`
  - Contour plot of matrix `Z` with `n` contour levels
- `[C,h] = contour_func(Z,v)`
  - Contour plot of matrix `Z` with contour lines corresponding to the values in `v`
- `[C,h] = contour_func(X,Y,Z)`
  - Contour plot of matrix `Z` over domain `X`, `Y`
- `[C,h] = contour_func(X,Y,Z,n)`
  - Contour plot of matrix `Z` over domain `X`, `Y` with `n` levels
- `[C,h] = contour_func(X,Y,Z,v)`
  - Contour plot of matrix `Z` over domain `X`, `Y` with contour lines corresponding to the values in `v`
- Similar for surface/mesh plots

# Vector Fields

- Visualize vector-valued function of two or three variables $\mathbf{F}(x, y) \in \mathbb{R}^2$ or $\mathbf{F}(x, y, z) \in \mathbb{R}^3$

| Command | Description |
|---|---|
| `feather` | Plot velocity vectors along horizontal |
| `quiver, quiver3` | Plot 2D, 3D velocity vectors from specified points |
| `compass` | Plot arrows emanating from origin |
| `streamslice` | Plot streamlines in slice planes |
| `streamline` | Plot streamlines of 2D, 3D vector data |

# Vector Fields

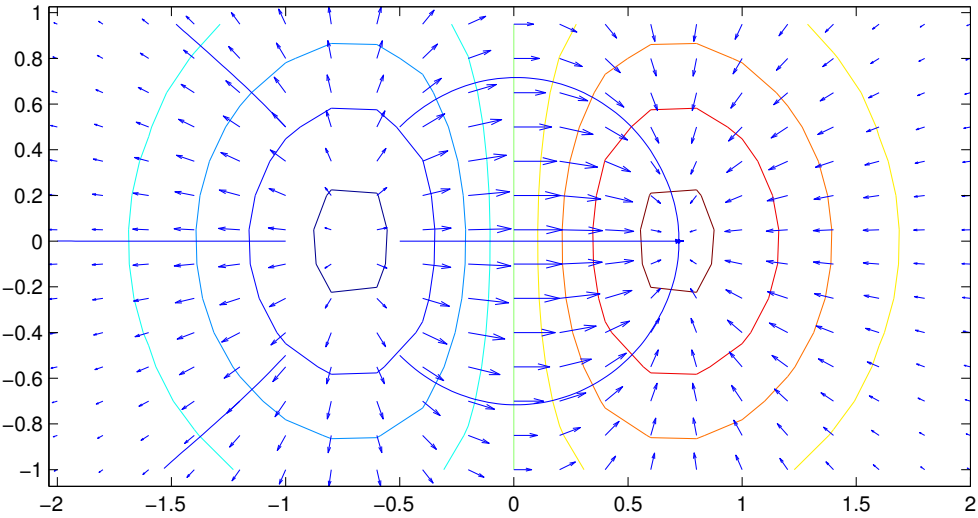



Figure: `contour`, `quiver`, `streamline`

# Vector fields: `quiver`, `feather`, `compass`

- Quiver plots
  - `h = quiver(X,Y,U,V)`
    - Displays velocity vectors as arrows with components `(u,v)` at the point `(x,y)`
    - `X,Y` generated with meshgrid
    - Additional call syntaxes to control display
  - `h = quiver3(X,Y,Z,U,V,W)`
    - Displays velocity vectors as arrows with components `(u,v,w)` at the point `(x,y,z)`
    - `X,Y,Z` generated with meshgrid
    - Additional call syntaxes to control display
  - `Quivergroup Properties`
- `feather`, `compass` similar, but simpler (don't require `X`, `Y`)

# Streamline-type plots

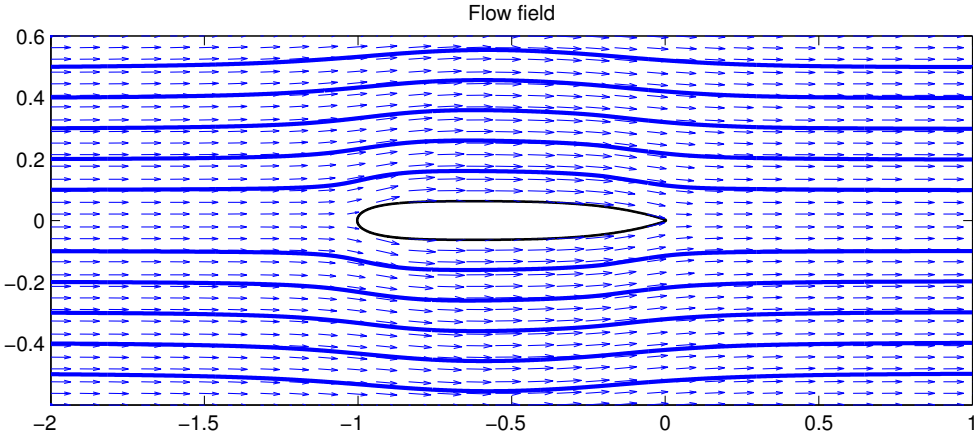



Figure: `quiver`, `streamline`, `fill` plots

# Streamline-type plots

- `streamline`, `stream2`, `stream3`
- Relevant for vector-valued functions of 2 or 3 variables ($\mathbf{F}(x, y)$ or $\mathbf{F}(x, y, z)$)
- Requires points to initialize streamlines
- Plot the trajectory of a particle through a vector field that was placed at a given position
  - `han=streamline(X,Y,Z,F1,F2,F3,StX,StY,StZ)`
    - `X, Y, Z` - grid generated with `meshgrid`
    - `F1,F2,F3` - vector components of $\mathbf{F}$ over grid
    - `StX, StY, StZ` - vectors (of the same size) specifying the starting location of the particles to trace

# Assignment

- Define `s = linspace(0,2*pi,100)`
- Plot $f(x, y) = \sin(xy)$ for $x, y \in [0, 2\pi]$ using any contour function
  - Make sure there are contour lines at $[-1.0, -0.75, -0.5, -0.25, 0, 0.25, 0.5, 0.75, 1.0]$
  - Use any colormap except `jet` (the default)
    - `autumn`, `bone`, `colorcube`, `cool`, `copper`, `flag`, `gray`, `hot`, `hsv`, `jet`, `lines`, `pink`, `prism`, `spring`, `summer`, `white`, `winter`
  - Use a colorbar
- Numerically compute $\nabla f(x, y)$ as `[Fx,Fy] = gradient(F)`
  - Make a `quiver` plot of $\nabla f(x, y)$
  - Plot streamline of $\nabla f(x, y)$ vector field, beginning at the point $(2, 2)$

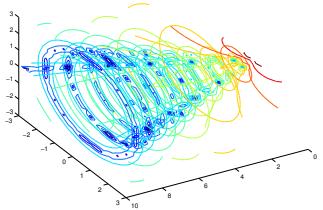
# Volume Visualization - Scalar Data

- Visualize scalar-valued function of two or three variables $f(x, y, z) \in \mathbb{R}$

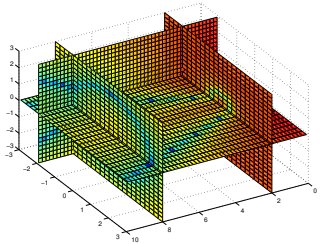
| Command | Description |
|---|---|
| `contourslice` | Draw contours in volume slice planes |
| `flow` | Simple function of three variables |
| `isocaps` | Compute isosurface end-cap geometry |
| `isocolors` | Compute isosurface and patch colors |
| `isonormals` | Compute normals of isosurface vertices |
| `isosurface` | Extract isosurface data from volume data |
| `slice` | Volumetric slice plot |

# Volume Visualization - Scalar Data

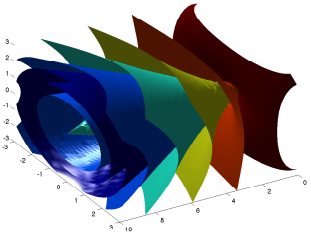
- Visualize scalar data defined over a volume.



(a) `contourslice`



(b) `slice`



(c) `isosurface`

# Slice-type plots

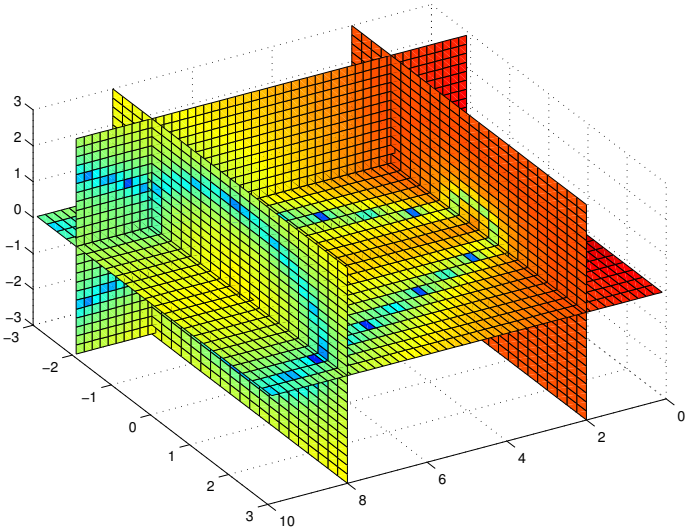



Figure: `slice`

# Slice-type plots

- `slice`, `contourslice`, `streamslice`
- Relevant for scalar- or vector-valued volume functions ($f(x, y, z)$ or $\mathbf{F}(x, y, z)$)
- Plot information in planar slices of the volumetric domain
  - `han = slice(X,Y,Z,F,Sx,Sy,Sz)`
    - `X`, `Y`, `Z` - grid generated by meshgrid
    - `F` = $\mathbf{F}$(`X`,`Y`,`Z`)
    - `Sx`, `Sy`, `Sz` vectors specifying location of slice planes in the $y - z$, $x - z$, and $x - y$ planes
  - `han = slice(X,Y,Z,F,XI,YI,ZI)`
    - `XI`, `YI`, `ZI` define *surface* (i.e. that could be plotted with surf) on which to plot `F`

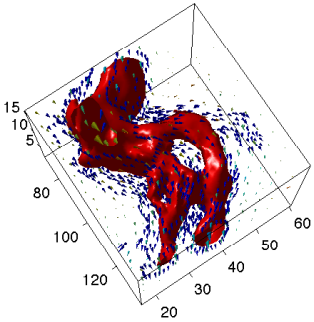
# Volume Visualization - Vector Data

- Visualize vector-valued function of three variables $\mathbf{F}(x, y, z) \in \mathbb{R}^3$

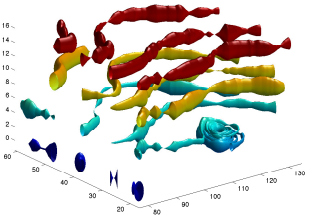
| Command | Description |
|---|---|
| `coneplot` | Plot velocity vectors as cone |
| `interpstreamspeed` | Interpolate stream-line vertices from flow speed |
| `stream2`, `stream3` | Compute 2D, 3D streamline data |
| `streamline` | Plot streamlines of 2D, 3D vector data |
| `streamparticles` | Plot stream particles |
| `streamribbon` | 3D stream ribbon plot |
| `streamslice` | Plot streamlines in slice planes |
| `streamtube` | Create 3D stream tube plot |

# Volume Visualization - Vector Data

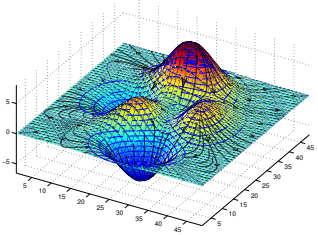
- Visualize vector data defined over a volume.




(a) `coneplot`



(b) `streamtube`



(c) `streamslice`

# Polygons

| Command | Description |
|---|---|
| `fill, fill3` | Fill 2D, 3D polygon |
| `patch` | Create filled polygons |
| `surf2patch` | Convert surface data to patch data |

- Patch graphics object
  - Core graphics object
  - `Patch Properties`

# Polygons

- `h = fill(X,Y,C)`
- `h = fill3(X,Y,Z,C)`
- `h = patch(X,Y,Z,C)`
  - For $m \times n$ matrices `X`, `Y`, `Z` draws $n$ polygons with vertices defined by each column
  - Color of each patch determined by `C`
    - If `C` is a string (`'r','w','y','b','k',...`), all polygons filled with specified color
    - If `C` is a $1 \times n$ vector, each polygon face is flat colored by `C(j)`
    - If `C` is a $1 \times n \times 3$ matrix, each polygon face colored by RGB value
    - If `C` is a $m \times n \times 3$ matrix, each vertex colored by RGB value and face color determined by interpolation

# Outline



# MATLAB File Exchange

The MATLAB File Exchange is a very useful forum for find solutions to many MATLAB-related problems

- 3D Visualization
- Data Analysis
- Data Import/Export
- Desktop Tools and Develepment Environment
- External Interfaces
- GUI Development
- Graphics
- Mathematics
- Object-Oriented Programming
- Programming and Data Types

# MATLAB File Exchange

The MATLAB File Exchange is a very useful forum for sharing solutions to many MATLAB-related problems

- Clean integration of MATLAB figures in LaTeX documents
  - `matlabfrag`, `figuremaker`, `export_fig`, `mcode`, `matrix2latex`, `matlab2tikz`
- Plot formatting and manipulation
  - `xticklabel_rotate`, `tight_subplot`
- Interfacing to iPhone, iPad, Android, Kinect devices
- Interfacing to Google Earth and Maps
- Much more

# Outline



# Motivation

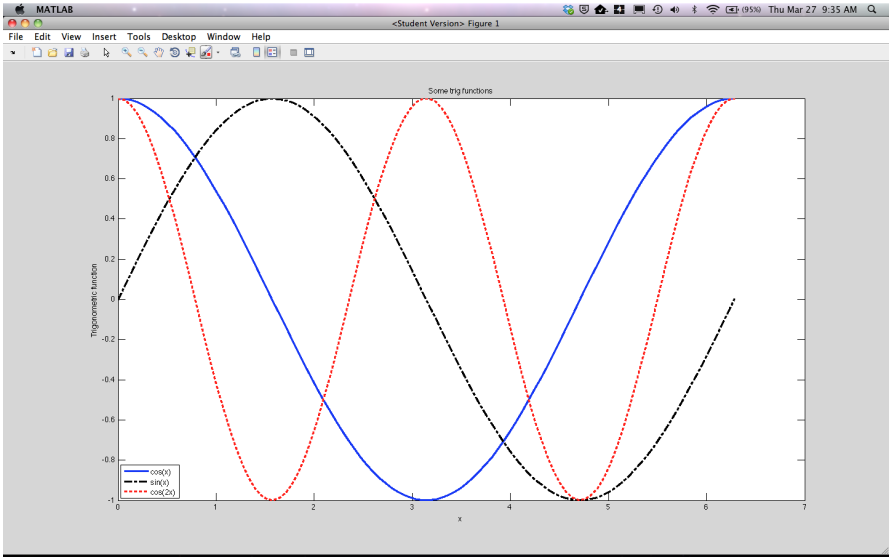
- Generating publication quality plots in MATLAB is not a trivial task
  - Plot annotation to match font size/style of document
  - Esthetic - dependent on type of publication
  - Legends can be difficult to work with
  - MATLAB figures not WYSIWYG by default
- Three fundamental approaches to generate plots for publications using MATLAB
  - Generate *plots* in MATLAB and import into document
    - Graphics handles to deal with esthetics
    - MATLAB File Exchange to integrate figures with LaTeX
  - Generate *data* in MATLAB and *plot* in document
    - TikZ/PGF popular choice for LaTeX
  - Hybrid (`matlab2tikz`)
- `high_quality_ex.m`

# WYSIWYG

MATLAB is not *What You See Is What You Get* (WYSIWYG) by default, when it comes to plotting

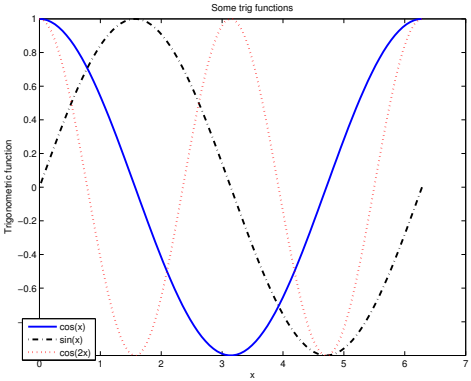
- Spend time making plot look exactly as you want
- Doesn't look the same when saved to file
  - Legend particularly annoying
  - Issues amplified when figure resized
- Very frustrating
- Force WYSIWYG
  - `set(gcf, 'PaperPositionMode', 'auto');`

# WYSIWYG Example

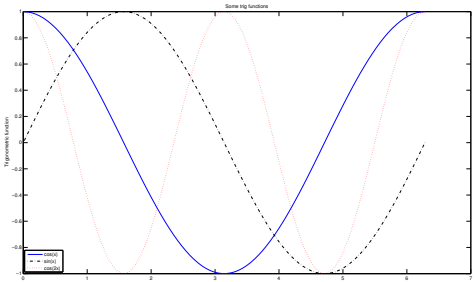


# WYSIWYG Example

(a) Without WYSIWYG




(b) With WYSIWYG




# High-Quality Graphics

This information is based on websites here and here.

- Generate plot with all lines/labels/annotations/legends/etc
- Set properties (graphics handles or interactively)
  - Figure width/height
  - Axes line width, object line width, marker size
  - Font sizes
- Save to figure to file
  - WYSIWYG
    - `set(gcf, 'PaperPositionMode', 'auto');`
  - Print to file for inclusion in document
    - `print(gcf,'-depsc2',filename)`
    - `matlabfrag(filename)`
    - `matlab2tikz(filename)`
- Fixing EPS file
  - Esthetics of dashed and dotted lines
  - `fixPSlinestyle`

# Important Properties - Figure

- Figure properties
  - `InvertHardCopy`
    - Change hardcopy to black objects on white background
  - `PaperPositionMode`
    - Forces the figure's size and location on the printed page to directly reflect the figure's size on the screen
  - `PaperOrientation`, `PaperPosition`, `PaperUnits`, `Position`, `Units`
    - Allows manual mapping from figure to paper

# Important Properties - Axes

- `Color`
  - Background color of plot
- `XLabel`, `YLabel`, `ZLabel`
- `XScale`, `YScale`, `ZScale`
- `XLim`, `YLim`, `ZLim`, `CLim`
- `XTick`, `XTickLabel`, `YTick`, `YTickLabel`, `ZTick`, `ZTickLabel`
  - Locations and labels of tick marks
- `XDir`, `YDir`, `ZDir`
  - Direction of axis ticks (ascending/descending)
- `XAxisLocation`, `YAxisLocation`
  - Place axis at left/right or top/bottom of axes
- `NextPlot`
  - Behavior when multiple objects added to axes

# Important Properties - Other

- Line object
  - `LineWidth`
  - `Marker`
  - `MarkerSize`
  - `MarkerEdgeColor`
  - `MarkerFaceColor`
- Legend object
  - `Position`, `Interpreter`
  - `LineStyle`
    - Type of line used to box legend
- Text object
  - `Position`, `Interpreter`

# Show Mcode

Two options to modify appearance of figure

- Interactively via MATLAB Figure GUI
  - Simplest and most popular
  - Not repeatable/automated
- Command line control via graphics handles
  - Less intuitive than interactive approach
  - Highly automated
  - Annoying trial/error when it comes to positioning/sizing

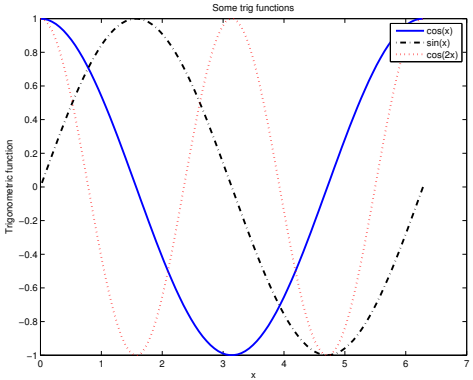
A hybrid approach that combines the above options is available

- Use GUI to interactively modify appearance of figure
- `Show Mcode` option to print underlying graphics handle operations to file
- Copy/paste into script for repeatability
- Demo: `show_mcode_ex.m`

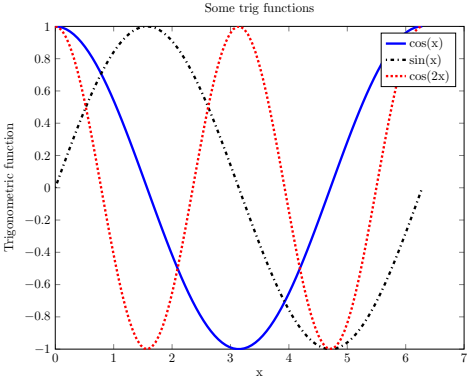
## matlab2tikz

- `matlab2tikz(FileName,...)`
  - Save figure in native LaTeX (TikZ/Pgfplots).
  - Import file in LaTeX (`\input` or `\includegraphics`)

(a) without `matlab2tikz`



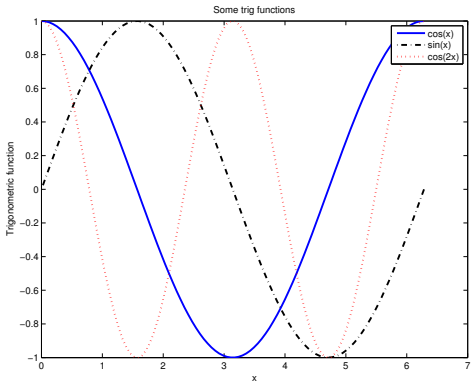

(b) with `matlab2tikz`



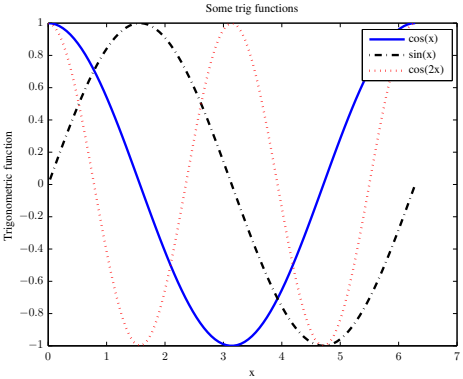

## matlabfrag

- `matlabfrag(FileName,OPTIONS)`
  - Exports a matlab figure to an .eps file and a .tex file for use with psfrag in LaTeX.
  - Doesn't seem to work well with beamer

(a) without `matlabfrag`

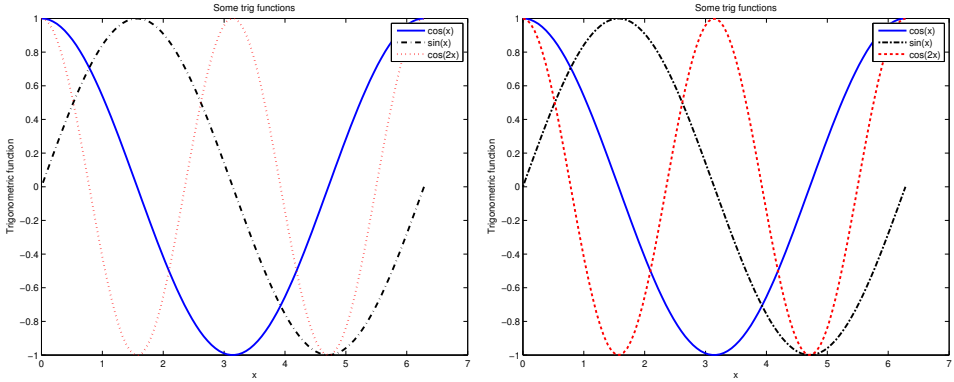



(b) with `matlabfrag`




## fixPSlinestyle

(a) without `fixPSlinestyle` (b) with `fixPSlinestyle`




`fixPSlinestyle` syntax

- `fixPSlinestyle(fname)`
- `fixPSlinestyle(old_fname,new_fname)`

# Outline



# Animation

Two main types of animation

- Interactive animation
  - Generate and display animation during execution of code
- Animation movies
  - Save animation in movie format

# Interactive Animation

- Generated by calling plot commands inside a loop with new data generated at each iteration
  - Before entering loop
    - Create figure and axes
    - Modify using handles to achieve desired appearance
    - Use command `set(gca,'nextplot','replacechildren')` to ensure only *children* of axes object will be replaced upon next plot command (will not modify axes properties)
  - During loop
    - Plotting command to generate data on plot
    - Modify object using handle to achieve desired appearance
    - Use command `drawnow` to draw object, otherwise will not be drawn until execution is complete (MATLAB optimization as plotting is expensive)
- Alternatively, modify `XData`, `YData`, `ZData` properties of initial plot object

# Interactive Animation

- Additionally, save sequence of plotting command as frames (`getframe`) and play back from MATLAB window (`movie`)
- `animate_ex.m`

Approach 1

```
fig=figure();
ax=axes();
obj=plot(..);
set(ax,'nextplot',...
    'replacechildren');
for j = 1:N
   obj=plot(..);
   drawnow;
end
```

Approach 2

```
fig=figure();
ax=axes();
obj=plot(..);
set(ax,'xlim',..,'ylim',..);
for j = 1:N
    set(obj,'xdata',..);
    set(obj,'ydata',..);
    drawnow;
end
```

# Animation Movies

Saving animations as movie files can be accomplished using `VideoWriter` class (`video_writer_ex.m`)

- `VideoWriter` enables creation of video files from MATLAB figures, still images, or MATLAB movies

```
writerObj = VideoWriter('my_movie.avi');  %Video obj
set(writerObj, 'FrameRate',10);  % Set the FPS
open(writerObj); % Open the video object
% Prepare the movie
figure; set(gca,'NextPlot','replaceChildren')
th = linspace(0,2*pi,100);
for j = th
    plot(sin(th),cos(th),'k-');  hold on;
    plot(sin(j),cos(j),'ro');
    writeVideo( writerObj, getframe );
end
close(writerObj); % Close the video object
```

## VideoWriter

- List of `VideoWriter` properties
  - Here on MathWorks website
  - `FrameRate` - rate of playback (cannot change after `open`)
  - `Quality` - integer between 0, 100
- `VideoWriter` methods
  - `open` - Open file for writing video data
  - `writeVideo` - Write video data to file
  - `close` - Close file after writing video data