

Lecture 13: Bonuses – Data Visualization and Management

B0B17MTB, BE0B17MTB – MATLAB

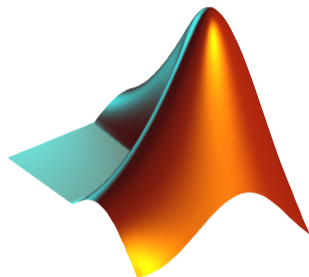
Miloslav Čapek, Viktor Adler, Vít Losenický, *et al.*

Department of Electromagnetic Field
Czech Technical University in Prague
Czech Republic
matlab@fel.cvut.cz

December 5, 2022
Winter semester 2022/23

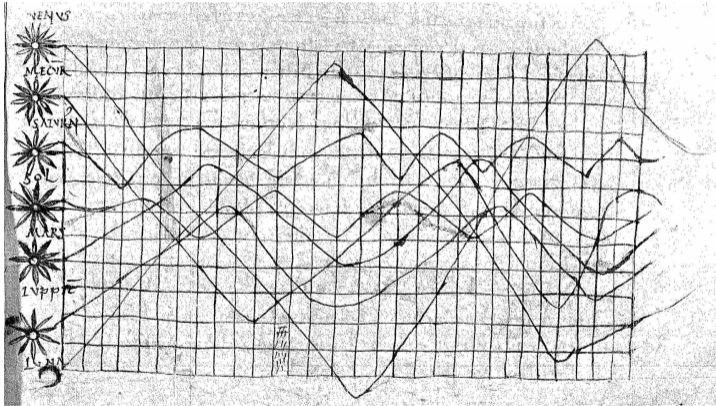


1. Graphs in MATLAB
2. Export of Graphics
3. Workflow with MATLAB2TikZ
4. Making Graphs Even Better...
5. Typesetting Recommendations
6. Recommended Tools and Resources



A Bit of History

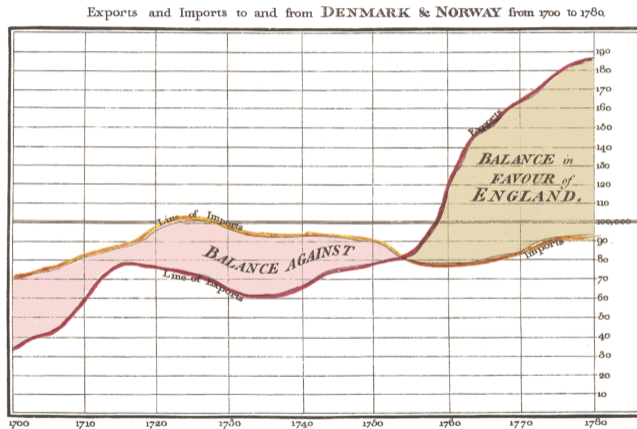
Attempts to visualize the structure of data are old...



Macrobius' Commentary on Cicero's Somnium Scipionis, the 10th century. Considered as the earliest graphical display.

A Bit of History

... and improved in time.



The Bottom line is divided into Years, the Right hand line into LIQ,000 each.
Published as the Act directs, 1st May 1786. by W^m. Playfair. *Scale weight 352, Strand, London.*

Commercial and Political Atlas, W. Playfair, 1786.



- ▶ Do you have data you want to visualize?



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- ▶ Start thinking of a way to present them properly!
 - ▶ What is the main information to be communicated?
 - ▶ Not all data have to be visualized (consider to use table or text description).
 - ▶ Details will be provided later.



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 4. Save or export the figure (EPS, PDF, PNG, MATLAB2Ti k Z).
 5. Archive the particular generating script (MATLAB `.m`), the particular data sets (`.tsv`, `.txt`), and the figure itself (`.tex`).



Data Preparation in MATLAB

Many ways how to get your data in:

- ▶ Upload them with Wizard (uiimport function, *Import Data*).
- ▶ Drag file and drop it to MATLAB Workspace window.
- ▶ You have already mat file, use `load('myFile.mat');`
- ▶ Load data with dedicated function, *e.g.*, for Excel:
`Data = xlsread('MTB_L10_Excel.xlsx', 'ImportFromExcel', 'A1:B4')`
- ▶ Use MATLAB to calculate what you need and generate data directly.



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Process the data to their final form:

- ▶ Normalization.
- ▶ Averages, etc.



Graph Overview (to get one: MATLAB → Plots → Catalog)

Plot Catalog
— □ ×

Search for all plots

- Line Plots
- Stem and Stair Plots
- Bar Plots
- Scatter Plots
- Graph Plots
- Pie Charts
- Histograms
- Polar Plots
- Geographic Plots
- Contour Plots
- Image Plots
- 3-D Surfaces
- Volumetrics
- Vector Fields
- Analytic Plots
- Control Toolbox Plots
- Curve Fitting Toolbox Plots
- DSP System Toolbox Plots
- Finance Toolbox Plots
- Image Processing Toolbox Plots
- Mapping Toolbox: Projected X-Y Plots
- Mapping Toolbox: Geographic Data Plots
- Signal Processing Toolbox: Filter Analysis
- Signal Processing Toolbox: Window Visualization
- Signal Processing Toolbox: Spectral Estimation
- Statistics And Machine Learning Toolbox Plots
- System Id: Parametric Model Evaluation
- System Id: Non-Parametric Analysis
- System Id: IDLTI Model Visualization
- System Id: IDLTI Model Simulation

Plotted Variables:

Syntax

```
plot(X,Y)
plot(X,Y,LineStyle)
plot(X1,Y1,...,Xn,Yn)
plot(X1,Y1,LineStyle1,...,Xn,Yn,LineStylen)

plot(Y)
plot(Y,LineStyle)

plot( __,Name,Value)
plot(ax, __)

h = plot( __)
```

Description

`plot(x,y)` creates a 2-D line plot of the data in `y` versus the corresponding values in `x`. example

- If `x` and `y` are both vectors, then they must have equal length. The `plot` function plots `y` versus `x`.
- If `x` and `y` are both matrices, then they must have equal size. The `plot` function plots columns of `y` versus columns of `x`.
- If one of `x` or `y` is a vector and the other is a matrix, then the matrix must have dimensions such that one of its dimensions equals the vector length. If the number of matrix rows equals the vector length, then the `plot` function plots each matrix column versus the vector. If the number of matrix columns equals the vector length, then the function plots each matrix row versus the vector. If the matrix is square, then the function plots each column versus the vector.
- If one of `x` or `y` is a scalar and the other is either a scalar or a vector, then the `plot` function plots discrete points. However, to see the points you must specify a marker symbol, for example, `plot(X,Y,'o')`.

`plot(X,Y,LineStyle)` sets the line style, marker symbol, and color. example

`plot(X1,Y1,...,Xn,Yn)` plots multiple `x`, `y` pairs using the same axes for all lines. example

`plot(X1,Y1,LineStyle1,...,Xn,Yn,LineStylen)` sets the line style, marker type, and color for each line. You can mix `X`, `Y`, `LineStyle` triplets with `X`, `Y` pairs. For example, `plot(X1,Y1,X2,Y2,LineStyle2,X3,Y3)`. example

`plot(Y)` creates a 2-D line plot of the data in `Y` versus the index of each value. example

- If `y` is a vector, then the `x`-axis scale ranges from 1 to `length(Y)`.
- If `y` is a matrix, then the `plot` function plots the columns of `y` versus their row number. The `x`-axis scale ranges from 1 to the number of rows in `y`.

Plot
Plot in New Figure
Close



Components of a Graph

Elements to take care of:

- ▶ traces (lines),
- ▶ markers,
- ▶ ticks,
- ▶ axes,
- ▶ labels,
- ▶ grid and box,
- ▶ legend,
- ▶ limits,
- ▶ caption.



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All elements have various attributes:

- ▶ color,
- ▶ size,
- ▶ opacity,
- ▶

For textual entries:

- ▶ font size,
- ▶ font name,
- ▶ typeface,
- ▶ ...



Components of a Graph – Example

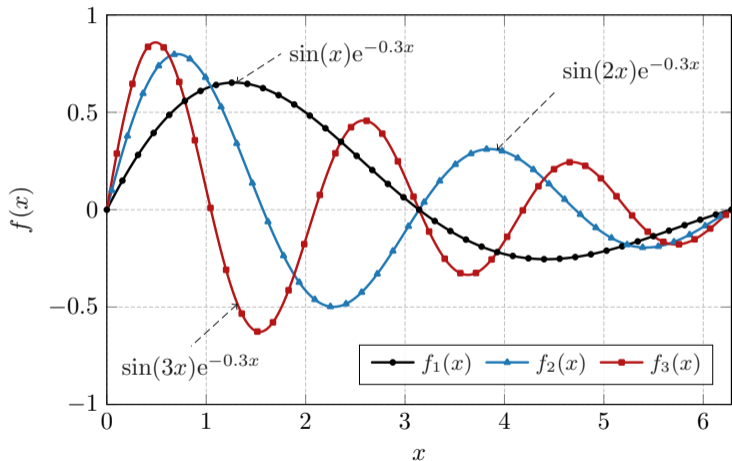


Fig. 1: Functions $\sin(nx)\exp(-0.3x)$.



Components of a Graph – Example

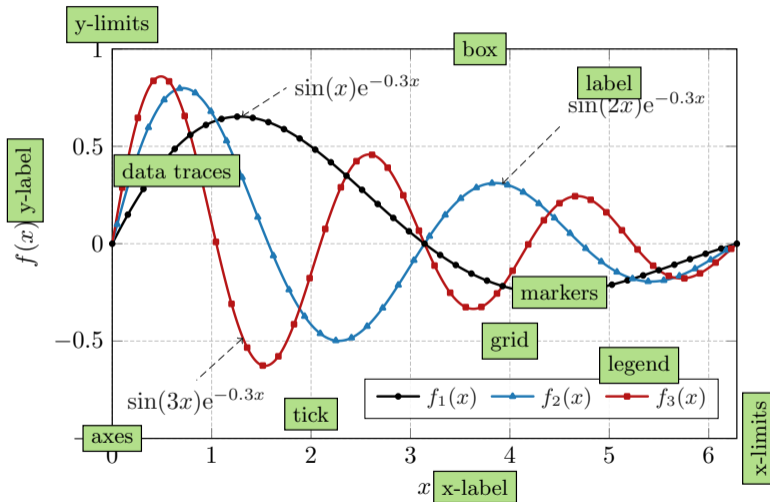
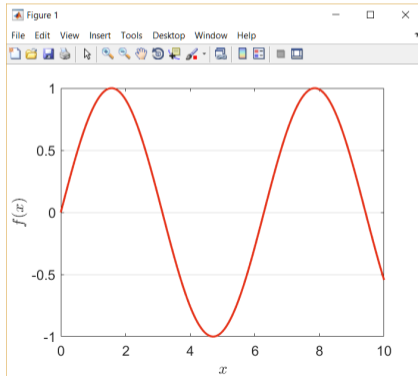


Fig. 1: Functions $\sin(nx) \exp(-0.3x)$.



Adjusting MATLAB Graph

- ▶ To realize what are the properties: `properties(obj)` or `get(obj)` (object has to exist).
- ▶ `obj.` + TAB to use whispering mode.



```
x = 0:0.01:10;
fx = sin(x);

fg = figure('color', 'w');
ax = axes('parent', fg);

trl = plot(x, fx);
trl.Color = [0.9 0.2 0.1];

ax.YGrid = true;
ax.YTick = -1:0.5:1;
ax.GridColor = [0 0 0];
ax.XLabel.String = '$x$';
ax.XLabel.Interpreter = 'LaTeX';

ax.YLabel.String = '$f(x)$';
ax.YLabel.Interpreter = 'LaTeX';

ax.FontSize = 14;
```



Saving Figure in MATLAB

To save a figure, either use `savefig(figHndl, 'myFigure')` or click on an GUI icon (diskette).

```
% A figure:
fig = figure;
ax = axes('parent', fig);
ln = plot(rand(10) - 1/2);

ax.FontSize = 14;

%% To save figure (or use GUI):
savefig(fig, 'myFigure.fig');

%% To open figure (or use GUI):
openfig('myFigure.fig');
```

- ▶ Some features from newer versions of MATLAB may not be supported when opened in older MATLAB release.

Export to JPG/PNG



EPS and PDF Export



Graph Preparation in Adobe Illustrator/Corel Draw



- ▶ Both Adobe and Corel offer great tools for vectors graphics.
- ▶ While the quality of outputs is excellent, it is harder to unify and automatize.

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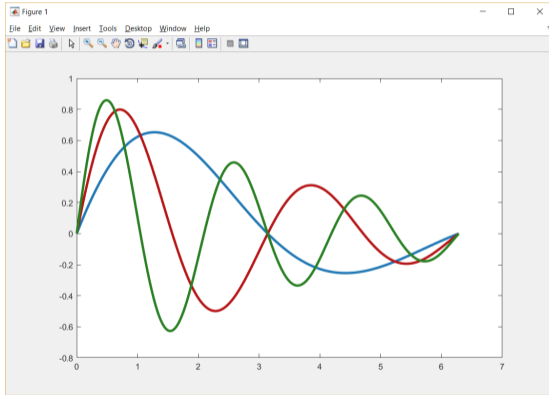
There is plethora of other highly specialized software:

- ▶ programming-based (matplotlib, GNUplot),
- ▶ 3D-graphs and schematics (Asymptote),
- ▶ for statistics (R),
- ▶ professional 3D and rendering (Blender, 3D Studio Max).

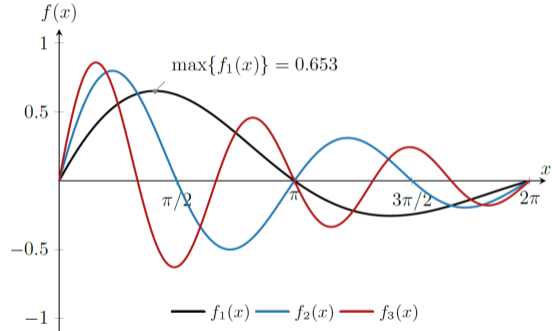




Decouple SW for Data Preparation and SW for Visualization



Default graph depicted in MATLAB.



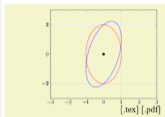
Graphics prepared in $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X} + \text{PGFPlots} + \text{TikZ}$.

Where to Start: Useful Galleries

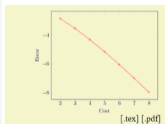
PGFPlots Gallery

The following graphics have been generated with the LaTeX Packages [PGFPlots](#) and [PGFPlotsTable](#).

They have been extracted from the reference manuals. [PGFPlots Home](#)



```
\begin{tikzpicture}
\begin{axis}[
xmin=-3, xmax=3,
ymin=-2, ymax=2,
extra x ticks={-1,1},
extra y ticks={-2,2},
extra tick style={grid=major},
]
\draw[red] \pgfextra{
\pgfpathellipse{\pgfplotspointaxisxy(0){0}}
{\pgfplotspointaxisdirectionxy(1){0}}
{\pgfplotspointaxisdirectionxy(0){2}}
% see also the documentation of
% 'axis direction cs' which
% allows a simpler way to draw this ellipse
};
\draw[blue] \pgfextra{
\pgfpathellipse{\pgfplotspointaxisxy(0){0}}
{\pgfplotspointaxisdirectionxy(1){1}}
{\pgfplotspointaxisdirectionxy(0){2}}
};
\addplot [only marks,mark=*] coordinates { (0,0) };
\end{axis}
\end{tikzpicture}
```



```
\begin{tikzpicture}
\begin{axis}[
xlabel=Cost,
ylabel=Error]
\addplot [color=red,mark=*] coordinates {
(2,-2.8559703)
(3,-3.5304977)
(4,-4.3050453)
(5,-5.1413136)
(6,-6.0322865)
(7,-6.9675052)
(8,-7.9377747)
};
\end{axis}
\end{tikzpicture}
```

Navigation

- Gallery main page
- About this gallery
- Contribute
- Show all examples

Subscribe to the TikZ examples RSS feed

Recently added examples

- Random city [PDF] [TEX] [Open in Overleaf]
- Circumscribed Parallelepiped [PDF] [TEX] [Open in Overleaf]
- Primcore Diagram, Classification of Phase Portraits [PDF] [TEX] [Open in Overleaf]
- Excised, Horizon-Penetrating Coordinates for Black Hole Spacetime [PDF] [TEX] [Open in Overleaf]

Features

Absolute positioning	4	Coordinate calculations	30	Matrices	25	Scopes	18
Angles	1	Coordinate systems	8	Mindmaps	4	Shadings	34
...

Almost impossible to start from scratch. Even skilled users start from existing graphics which they adapt (PGFPlots Gallery [here](#)).

Use Google, the community is huge and friendly. Ask for help or use someone's code snippets (TikZ and PGF examples [here](#)).

Visualization

Ugly × Fancy Graphs

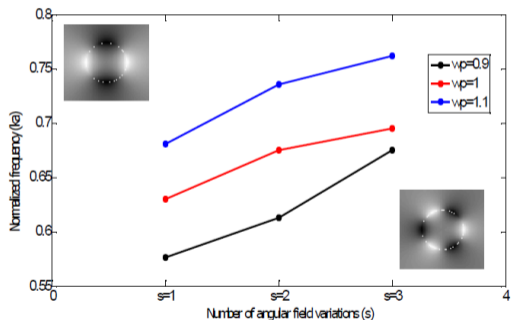


Clarity, simplicity, temperance.

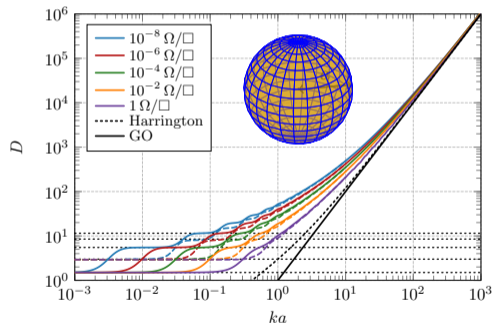


Ugly × Fancy Graphs

Clarity, simplicity, temperance.



A bad figure almost in every aspect (anonymous authors).



A better figure. Still not perfect (the author of the talk).

Visualization



Imperfection is Common, Minimize It!

Analysis of one volume of Science journal

W. Cleveland^a analyzed vol. 207 of Science journal (1980);

- ▶ 249 articles (67% containing graphs),
- ▶ 377 graphs in total.

^aW. S. Cleveland: The Elements of Graphing Data. Wadsworth Advanced Book Program, 1985.



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He found that 30% of all graphs had at least one of the following types:

1. **Explanation** (15.4%) – Something on the graph was not explained.
2. **Discrimination** (10.10%) – Items on the graph could not be easily distinguished due to the design or size of the graph.
3. **Construction** (6.4%) – A mistake was made in the construction of the graph (tick marks incorrectly spaced, mislabeling, etc.).
4. **Degraded Image** (6.4%) – Some aspects of the graph was missing or partially missing due to poor reproduction.

^aW. S. Cleveland: The Elements of Graphing Data. Wadsworth Advanced Book Program, 1985.



Rules to Remember¹

OPEN ACCESS Freely available online

PLOS COMPUTATIONAL BIOLOGY

Editorial

Ten Simple Rules for Better Figures



Nicolas P. Rougier^{1,2,3*}, Michael Droettboom⁴, Philip E. Bourne⁵

¹INRIA Bordeaux Sud-Ouest, Talence, France, ²LaBRI, UMR 5800 CNRS, Talence, France, ³Institute of Neurodegenerative Diseases, UMR 5293 CNRS, Bordeaux, France, ⁴Space Telescope Science Institute, Baltimore, Maryland, United States of America, ⁵Office of the Director, The National Institutes of Health, Bethesda, Maryland, United States of America

- | | |
|---|-----------------------------|
| 1. Know Your Audience | 6 Use Color Effectively |
| 2. Identify Your Message | 6 Do Not Mislead the Reader |
| 3. Adapt the Figure to the Support Medium | 6 Avoid “Chartjunk” |
| 4. Captions Are Not Optional | 6 Message Trumps Beauty |
| 5. Do Not Trust the Defaults | 6 Get the Right Tool |

¹N. P. Rougier, M. Droettboom, and P. E. Bourne: Ten Simple Rules for Better Figures, PLOS Computational Biology, vol. 10, pp. 1–7, 2014. ([here](#))



Organization of Figures

- ▶ Figures should be first referred to in the text.
- ▶ Figures should appear in the order of their numbers in the text.
- ▶ Figures should stay within the page margins.
- ▶ Axes need a label with units.
- ▶ Figures should be legible (font size comparable with font size of text in the body).
- ▶ When referring a figure, use “Figure 1” or “Fig. 1”, *i.e.*, capitalize “F”.
- ▶ Good if a reference is taken as a part of the sentence:
 - ▶ “As depicted in “Figure 1”...”
 - ▶ “Results suggest that..., see Fig. 1.”

Variables and Units



$$f_0 = \{f_{\text{quantity}}\} [f_{\text{unit}}] = 12\,345(67) \text{ Hz}$$

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 - ▶ Different units are separated by a space (N m not Nm) or a c-dot ($1 \text{ N} \cdot \text{m}$).
 - ▶ Prefixes are written in roman with no space between symbol and prefix (1 THz vs. 1 T Hz vs. 1 T Hz vs. 1 THz).



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 - ▶ $l = 1.31 \times 10^3 \text{ m}$, $l = 1.31 \cdot 10^3 \text{ m}$, $S = 20 \text{ m} \times 30 \text{ m}$.

Decimal Sign and Exponents



- ▶ Decimal sign is either a comma or a point (1,234 or 1.234).



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- ▶ Number of significant digits (410 008 vs 410 000 vs $4.1 \cdot 10^5$).



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▶ Unit prefixes

▶ Mathematical symbols

▶ Guide for the use of SI units

Constants



mathematical Dimensionless with fixed numerical value of no direct physical meaning or necessity of a physical measurement.

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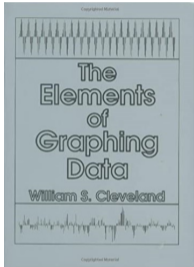
- ▶ Examples: speed of light in vacuum (c_0), electron charge (e), permittivity of vacuum (ε), impedance of vacuum (Z_0).

mathematical always in **roman** type, *i.e.*, $e^{j\pi} + 1 = 0$

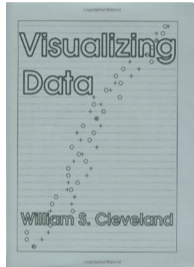
physical always in **italic** type, *i.e.*, $2c_0$, *cf.* e^2 vs. e^2



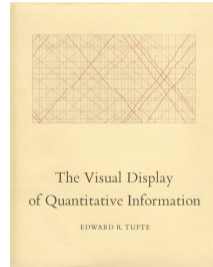
Recommended Literature



Cleveland, W. S.:
The Elements of
Graphing Data



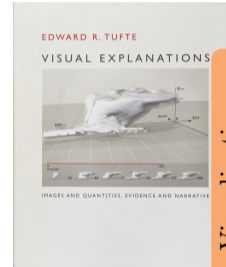
Cleveland, W. S.:
Visualizing Data



Tufte, E. R.: The
Visual Display of
Quantitative
Information



Tufte, E. R.:
Envisioning
Information



Tufte, E. R.: Visual
Explanation



Packages to Get

Must have

1. L^AT_EX distribution [▶ MikTeX](#)
2. L^AT_EX editor [▶ TeXstudio](#)
3. L^AT_EX packaged (can be installed on the fly)
4. Spell-checker [▶ How to install](#)
5. Reference database editor [▶ JabRef](#)

Optional

1. Matlab2TikZ [▶ Matlab2TikZ](#)
2. GhostScript [▶ GhostScript](#)
3. GhostViewer [▶ GhostViewer](#)
4. GNUplot [▶ GNUplot](#)
5. GeoZebra [▶ GeoZebra](#)
6. MeshLab [▶ MeshLab](#)
7. ParaView [▶ ParaView](#)
8. Asymptote [▶ Asymptote](#)

Codes from MATLAB fileexchange (mcode, cbrewer, fig2u3d, vrml, export_fig).



Overleaf

Overleaf (2018) = ShareLaTeX (before 2018) + Overleaf (before 2018)

- ▶ On-line tool for collaborative L^AT_EX writing.
- ▶ Standard account for free (some limitations).
- ▶ A plethora of standardized templates.

▶ Overleaf

- ▶ Web page, login, application.
- ▶ Sharing, GIT.
- ▶ History, back up.
- ▶ Types of documents (report, paper, CV, project proposal), templates.
- ▶ External style files, animate.

Questions?

B0B17MTB, BE0B17MTB – MATLAB
matlab@fel.cvut.cz

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