

# Lecture 13: Bonuses – Data Visualization and Management

B0B17MTB, BE0B17MTB – MATLAB

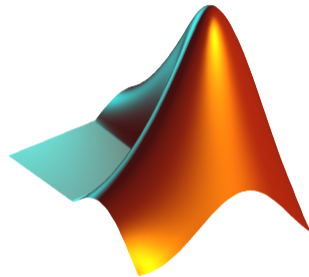
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Czech Republic  
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December 12  
Winter semester 2021/22

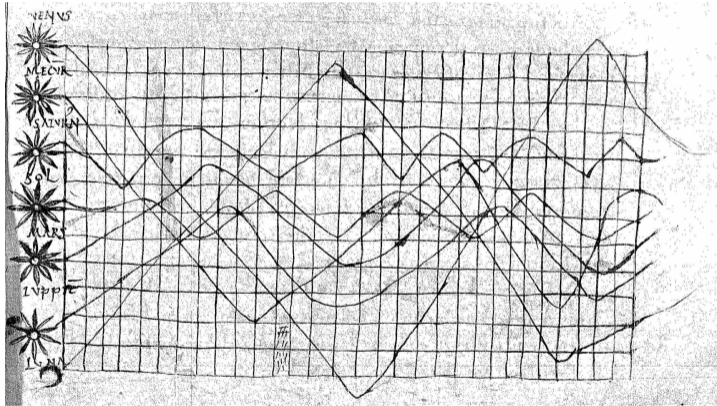


1. Graphs in MATLAB
2. Export of Graphics
3. Workflow with MATLAB2TikZ
4. Making Graphs Even Better...
5. Typesetting Recommendations
6. Recommended Tools and Resources



# A Bit of History

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



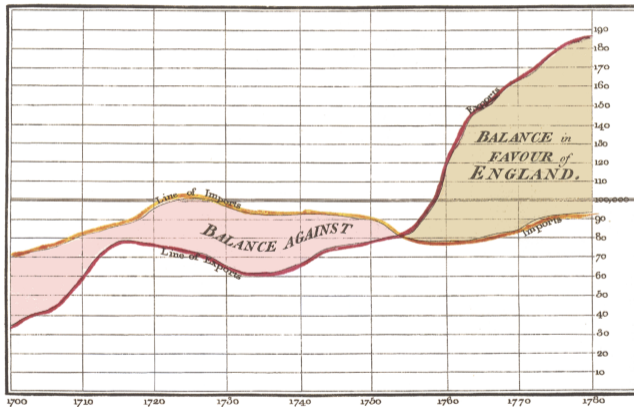
*Macrobius' Commentary on Cicero's Somnium Scipionis*, the 10th century. Considered as the earliest graphical display.

# A Bit of History

... and improved in time.



Exports and Imports to and from DENMARK & NORWAY from 1700 to 1780.



*The Bottom line is divided into Years, the Right hand line into £10,000 each.*  
Published as the Act directs, 1<sup>st</sup> May 1786. by W<sup>m</sup>. 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

plot(Data)  
2-D line graph using linear axes

Plot as multiple series  
Plots each series on the same plot

Plot as multiple series vs. first input  
Plots the second and later series again...

plotyy(Data)  
Graphs with y tick labels on the left an...

semilogx(Data)  
Semi-log scale plot

semilogy(Data)  
Semi-log scale plot

loglog(Data)  
Log-log scale plot

area(Data)  
Filled area plot

errorbar(Data)  
Error bar plot

errorbar (horizontal)  
Horizontal error bar plot

plot3(Data)  
3-D line graph using linear axes

comet(Data)  
Comet-like trajectory

Plotted Variables: Data

**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.

`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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- ▶ caption.

All elements have various attributes:

- ▶ color,
- ▶ size,
- ▶ opacity,
- ▶ ....

For textual entries:

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





# Components of a Graph – Example

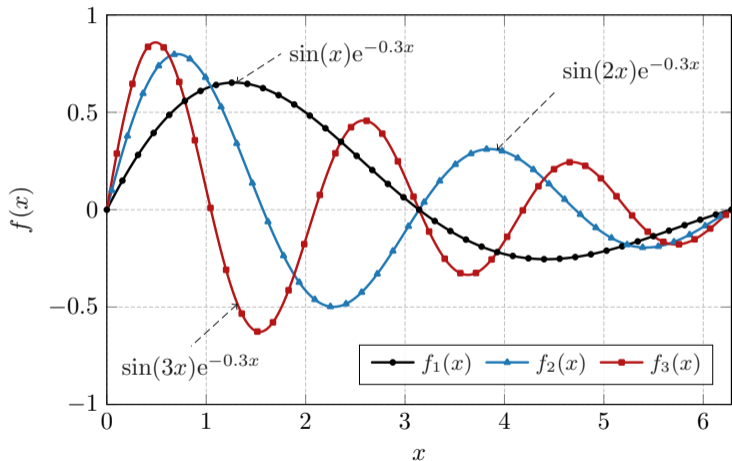


Fig. 1: Functions  $\sin(nx)\exp(-0.3x)$ .



# Components of a Graph – Example

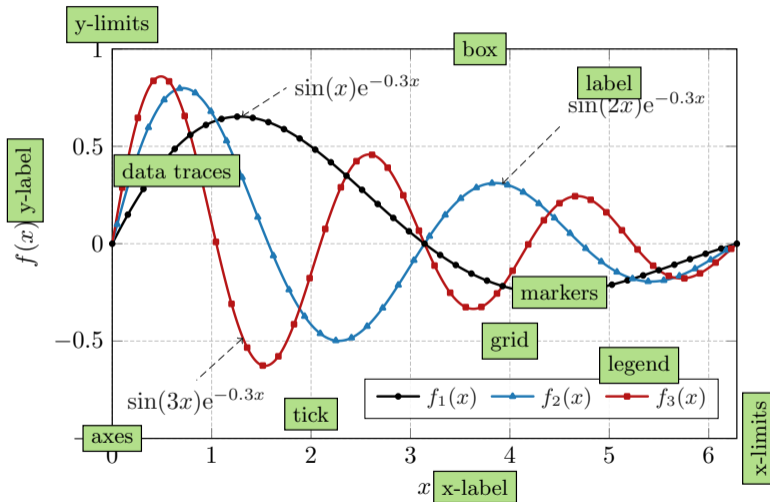
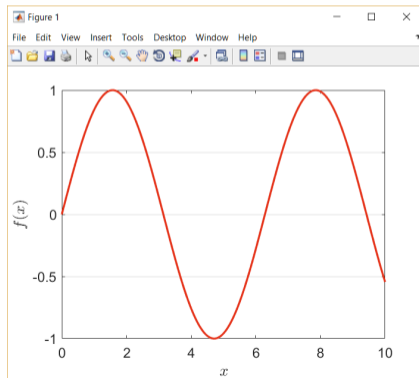


Fig. 1: Functions  $\sin(nx) \exp(-0.3x)$ .



# 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:

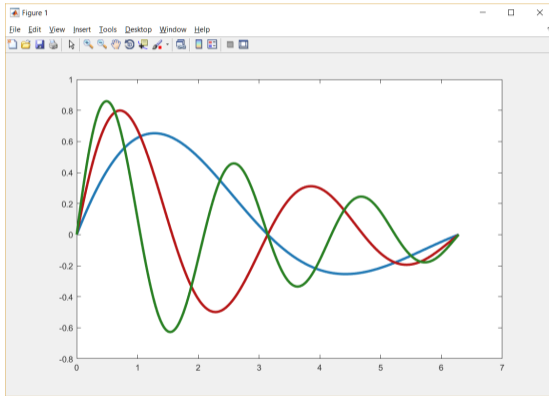
- ▶ programming-based (matplotlib, GNUplot),
- ▶ 3D-graphs and schematics (Asymptote),
- ▶ for statistics (R),
- ▶ professional 3D and rendering (Blender, 3D Studio Max).



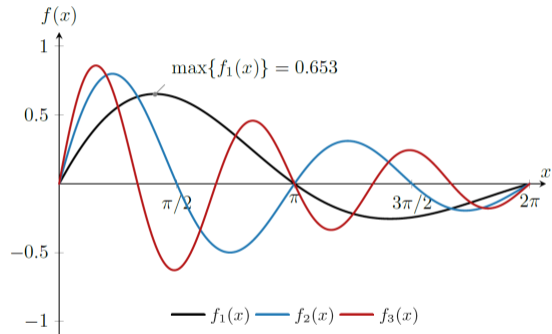




# Decouple SW for Data Preparation and SW for Visualization



Default graph depicted in MATLAB.



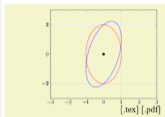
Graphics prepared in  $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X} + \text{PGFPlots} + \text{TikZ}$ .

# Where to Start: Useful Galleries

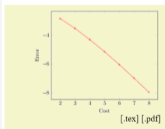
## PGFPlots Gallery

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}
```

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

**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]
- Primcane Diagram, Classification of Phase Portraits [PDF] [TEX] [Open in Overleaf]
- Excised, Horizon-Penetrating Coordinates for Black Hole Spacetime [PDF] [TEX] [Open in Overleaf]

[Show all examples](#) | [Show in chronological order](#) | [Show as list](#)

| Features             |   |                         |    |          |    |
|----------------------|---|-------------------------|----|----------|----|
| Absolute positioning | 4 | Coordinate calculations | 30 | Matrices | 25 |
| Angles               | 1 | Coordinate systems      | 8  | Mindmaps | 4  |
| Axis                 | 1 | Decorations             | 45 | Shadings | 34 |
| Axis labels          | 1 | Diagrams                | 10 | Shadows  | 1  |

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

# Ugly × Fancy Graphs

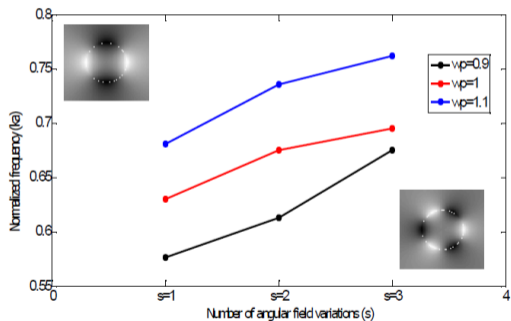


Clarity, simplicity, temperance.

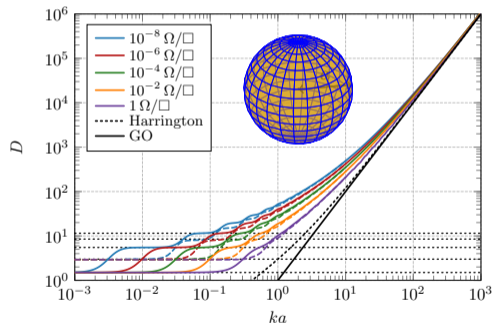


# Ugly × Fancy Graphs

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<sup>a</sup> analyzed vol. 207 of Science journal (1980);

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

---

<sup>a</sup>W. 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.

---

<sup>a</sup>W. S. Cleveland: The Elements of Graphing Data. Wadsworth Advanced Book Program, 1985.



# Rules to Remember<sup>1</sup>

OPEN ACCESS Freely available online

PLOS COMPUTATIONAL BIOLOGY

Editorial

## Ten Simple Rules for Better Figures



Nicolas P. Rougier<sup>1,2,3\*</sup>, Michael Droettboom<sup>4</sup>, Philip E. Bourne<sup>5</sup>

<sup>1</sup>INRIA Bordeaux Sud-Ouest, Talence, France, <sup>2</sup>LaBRI, UMR 5800 CNRS, Talence, France, <sup>3</sup>Institute of Neurodegenerative Diseases, UMR 5293 CNRS, Bordeaux, France, <sup>4</sup>Space Telescope Science Institute, Baltimore, Maryland, United States of America, <sup>5</sup>Office 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        |

<sup>1</sup>N. 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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  - ▶ Note that  $12\,345 \pm 67 \text{ Hz}$  is incorrect from mathematical point of view.

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  - ▶ Different units are separated by a space (N m not Nm) or a c-dot ( $1\text{ N} \cdot \text{m}$ ).





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  - ▶ Different units are separated by a space (N m not Nm) or a c-dot (1 N · 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 T Hz).



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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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- ▶ Decimal sign is either a comma or a point (1,234 or 1.234).
- ▶ Numbers can be grouped from the decimal sign or from left (12 345.678 9 or 1 234), use small space then.



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- ▶ Numbers can be grouped from the decimal sign or from left (12 345.678 9 or 1 234), use small space then.
- ▶ Negative exponents should be avoided when the numbers are used, except when the base 10 is used ( $10^{-5}$  not  $4^{-8}$ , type  $1/4^8$  instead).



# Decimal Sign and Exponents

- ▶ Decimal sign is either a comma or a point (1,234 or 1.234).
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- ▶ Multiplication with  $\cdot$  or  $\times$ . Do not use any symbol for products like  $ab$ ,  $\mathbf{Ax}$ , etc. Use when multiplication operation has to be highlighted, *i.e.*, multi-line equation or  $2.125 \cdot 10^8$ .



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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.

**physical** Often carry dimensions, they are universal and constant in time.



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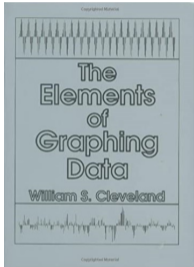
- ▶ Examples: speed of light in vacuum ( $c_0$ ), electron charge ( $e$ ), permittivity of vacuum ( $\varepsilon$ ), impedance of vacuum ( $Z_0$ ).

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

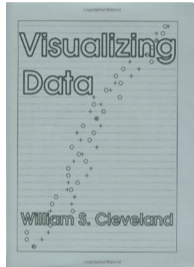
**physical** always in **italic** type, *i.e.*,  $2c_0$ , *cf.*  $e^2$  vs.  $e^2$



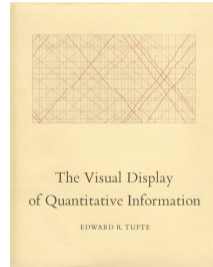
# Recommended Literature



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



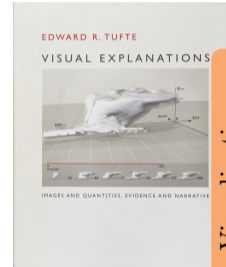
Cleveland, W. S.:  
Visualizing Data



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<sup>A</sup>T<sub>E</sub>X distribution [▶ MikTeX](#)
2. L<sup>A</sup>T<sub>E</sub>X editor [▶ TeXstudio](#)
3. L<sup>A</sup>T<sub>E</sub>X 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<sup>A</sup>T<sub>E</sub>X 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

December 12  
Winter semester 2021/22

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