Graphics for LaTeX users

Agostino De Marco

Università degli Studi di Napoli Federico II
Dipartimento di Ingegneria Industriale

Gruppo Utilizzatori Italiani di TeX

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Outline

General guidelines on illustration design

Drawing with LaTeX-aware software

- Using `Inkscape` + `TexText` extension

Drawing with natively available LaTeX environments/packages

- The standard environment `picture`
- The package `pstricks` (PostScript)
- The package `tikz`

Data plots with package `pgfplots`

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Illustrations

The term ***illustration*** refers to all kind of pictorial graphics — photographs, drawings, diagrams, and schematics.

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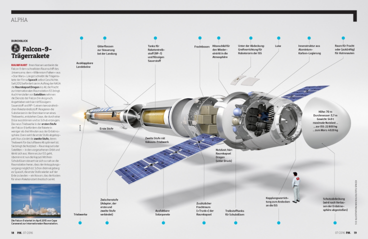
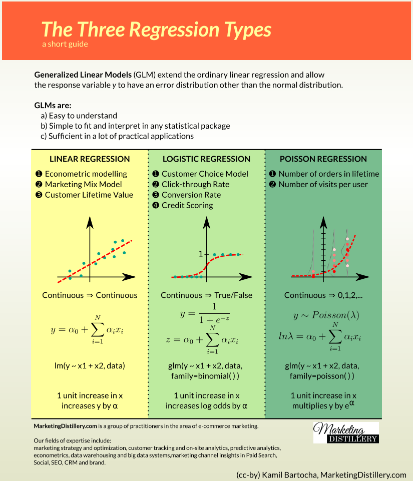
LOGOTYPE
LOGISTICS
ABOUT
SEA FREIGHT
CARGO
RO-RO CARGO
1
2
3
infographic





The Three Regression Types

a short guide

Generalized Linear Models (GLM) extend the ordinary linear regression and allow the response variable *y* to have an error distribution other than the normal distribution.

GLMs are:

a) Easy to understand
b) Simple to fit and interpret in any statistical package
c) Sufficient in a lot of practical applications

LINEAR REGRESSION	LOGISTIC REGRESSION	POISSON REGRESSION
❶ Econometric modelling ❷ Marketing Mix Model ❸ Customer Lifetime Value	❶ Customer Choice Model ❷ Click-through Rate ❸ Conversion Rate ❹ Credit Scoring	❶ Number of orders in lifetime ❷ Number of visits per user
Continuous ⇒ Continuous	Continuous ⇒ True/False	Continuous ⇒ 0,1,2,...
$y = \alpha_0 + \sum_{i=1}^{N} \alpha_i x_i$	$y = \frac{1}{1+e^{-z}}$ $z = \alpha_0 + \sum_{i=1}^{N} \alpha_i x_i$	$y \sim Poisson(\lambda)$ $ln\lambda = \alpha_0 + \sum_{i=1}^{N} \alpha_i x_i$
lm(y ~ x1 + x2, data)	glm(y ~ x1 + x2, data, family=binomial( ))	glm(y ~ x1 + x2, data, family=poisson( ))
1 unit increase in x increases y by α	1 unit increase in x increases log odds by α	1 unit increase in x multiplies y by e^{α}

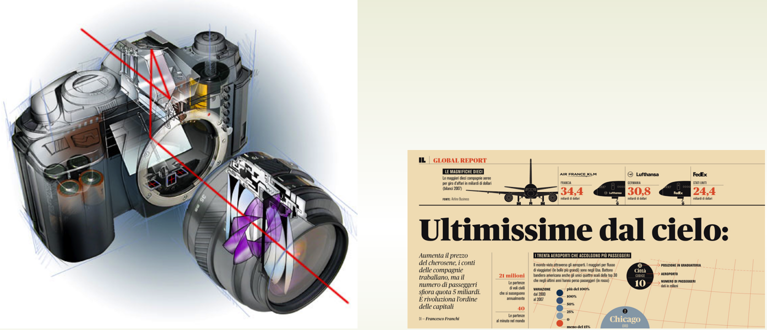
MarketingDistillery.com is a group of practitioners in the area of e-commerce marketing.

Our fields of expertise include:
marketing strategy and optimization, customer tracking and on-site analytics, predictive analytics, econometrics, data warehousing and big data systems,marketing channel insights in Paid Search, Social, SEO, CRM and brand.

Marketing DISTILLERY

(cc-by) Kamil Bartocha, MarketingDistillery.com

Illustrations



IL | GLOBAL REPORT

LE MAGNIFICHE DIECI

Le maggiori dieci compagnie aeree per giro d'affari in miliardi di dollari (bilanci 2007)

FONTE: Airline Business

AIR FRANCE KLM	Lufthansa	FedEx
FRANCIA	GERMANIA	STATI UNITI
34,4	30,8	24,4
miliardi di dollari	miliardi di dollari	miliardi di dollari

Ultimissime dal cielo:

Aumenta il prezzo del cherosene, i conti delle compagnie traballano, ma il numero di passeggeri sfiora quota 5 miliardi. E rivoluziona l'ordine delle capitali

DI – ***Francesco Franchi***

21 milioni
Le partenze di voli civili che si susseguono annualmente

40
Le partenze al minuto nel mondo

I TRENTA AEROPORTI CHE ACCOLGONO PIÙ PASSEGGERI

Il mondo visto attraverso gli aeroporti. I maggiori per flusso di viaggiatori (le bolle più grandi) sono negli Usa. Battono bandiera americana anche gli unici quattro scali della top 30 che negli ultimi anni hanno perso passeggeri (in rosso)

VARIAZIONE
dal 2000
al 2007

(a) An example of technical illustration showing the Reflex principle.

(b) A newspaper illustration. This example shows a particular kind of artwork known as 'infographics.'

Figure 1: Examples of on-the-job technical illustrations.

Illustrations

It is important in typography to ***maintain a consistency between text and graphics***.

Illustrations

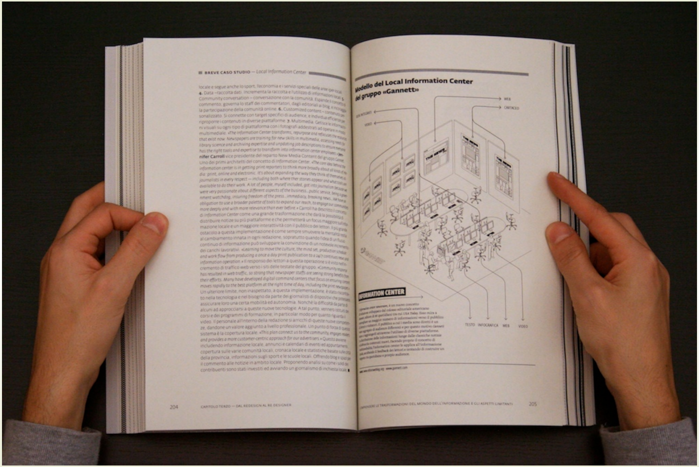

BREVE CASO STUDIO — Local Information Center
Modello del Local Information Center del gruppo «Gannett»
WEB
CARTACEO
VIDEO
TESTO
INFOGRAFICA
WEB
VIDEO
204
205

Figure 2: A technical book in the hands of a reader. The right-hand page contains a full-height annotated illustration.

Illustrations – Benefits

Benefits coming from a careful use of ***visual material in technical documents***:

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- Graphics enable writers to ***convey information to readers who do not share a common language*** with the writers — or with each other.
- ***Graphics communicate information so effectively that they sometimes convey the entire message*** (see Figure 1a, Reflex camera).

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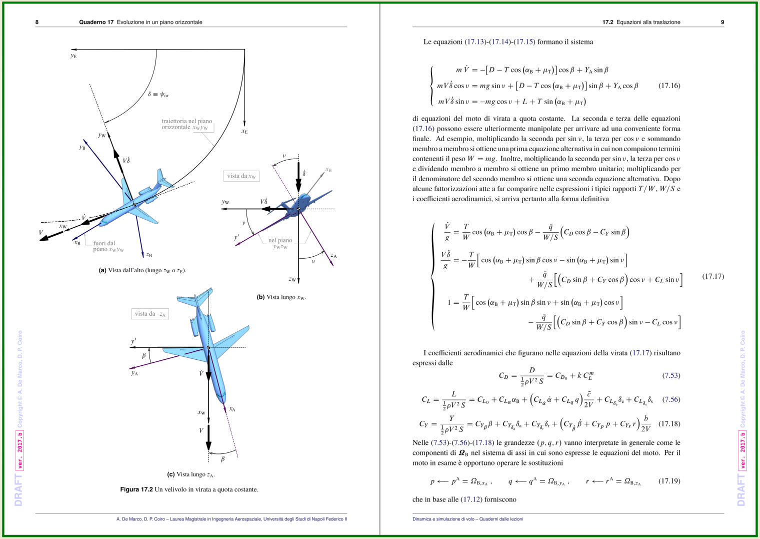
Design graphics with a special ***focus on usability***.

Graphics should have the same good qualities of author's prose, ***easy for readers to understand and use***.

Engineering illustrations – Example



(a) Vista dall'alto (lungo z_{W} o z_{E}).

(b) Vista lungo x_{W}.

(c) Vista lungo z_{A}.

Figura 17.2 Un velivolo in virata a quota costante.

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Le equazioni (17.13)-(17.14)-(17.15) formano il sistema

$$\begin{cases} m\,\dot{V} = -\big[D - T\cos\left(\alpha_{\mathrm{B}} + \mu_{\mathrm{T}}\right)\big]\cos\beta + Y_{\mathrm{A}}\sin\beta \\ mV\dot{\delta}\cos\nu = mg\sin\nu + \big[D - T\cos\left(\alpha_{\mathrm{B}} + \mu_{\mathrm{T}}\right)\big]\sin\beta + Y_{\mathrm{A}}\cos\beta \\ mV\dot{\delta}\sin\nu = -mg\cos\nu + L + T\sin\left(\alpha_{\mathrm{B}} + \mu_{\mathrm{T}}\right) \end{cases} \tag{17.16}$$

di equazioni del moto di virata a quota costante. La seconda e terza delle equazioni (17.16) possono essere ulteriormente manipolate per arrivare ad una conveniente forma finale. Ad esempio, moltiplicando la seconda per $\sin\nu$, la terza per $\cos\nu$ e sommando membro a membro si ottiene una prima equazione alternativa in cui non compaiono termini contenenti il peso $W = mg$. Inoltre, moltiplicando la seconda per $\sin\nu$, la terza per $\cos\nu$ e dividendo membro a membro si ottiene un primo membro unitario; moltiplicando per il denominatore del secondo membro si ottiene una seconda equazione alternativa. Dopo alcune fattorizzazioni atte a far comparire nelle espressioni i tipici rapporti T/W, W/S e i coefficienti aerodinamici, si arriva pertanto alla forma definitiva

$$\begin{cases} \dfrac{\dot{V}}{g} = \dfrac{T}{W}\cos\left(\alpha_{\mathrm{B}} + \mu_{\mathrm{T}}\right)\cos\beta - \dfrac{\bar{q}}{W/S}\Big(C_D\cos\beta - C_Y\sin\beta\Big) \\ \dfrac{V\dot{\delta}}{g} = -\dfrac{T}{W}\Big[\cos\left(\alpha_{\mathrm{B}} + \mu_{\mathrm{T}}\right)\sin\beta\cos\nu - \sin\left(\alpha_{\mathrm{B}} + \mu_{\mathrm{T}}\right)\sin\nu\Big] \\ \qquad\qquad + \dfrac{\bar{q}}{W/S}\Big[\Big(C_D\sin\beta + C_Y\cos\beta\Big)\cos\nu + C_L\sin\nu\Big] \\ 1 = \dfrac{T}{W}\Big[\cos\left(\alpha_{\mathrm{B}} + \mu_{\mathrm{T}}\right)\sin\beta\sin\nu + \sin\left(\alpha_{\mathrm{B}} + \mu_{\mathrm{T}}\right)\cos\nu\Big] \\ \qquad\qquad - \dfrac{\bar{q}}{W/S}\Big[\Big(C_D\sin\beta + C_Y\cos\beta\Big)\sin\nu - C_L\cos\nu\Big] \end{cases} \tag{17.17}$$

I coefficienti aerodinamici che figurano nelle equazioni della virata (17.17) risultano espressi dalle

$$C_D = \frac{D}{\frac{1}{2}\rho V^2 S} = C_{D_0} + k\,C_L^m \tag{7.53}$$

$$C_L = \frac{L}{\frac{1}{2}\rho V^2 S} = C_{L_0} + C_{L\alpha}\alpha_{\mathrm{B}} + \Big(C_{L_{\dot{\alpha}}}\dot{\alpha} + C_{L_q}\,q\Big)\frac{\bar{c}}{2V} + C_{L_{\delta_{\mathrm{e}}}}\delta_{\mathrm{e}} + C_{L_{\delta_{\mathrm{s}}}}\delta_{\mathrm{s}} \tag{7.56}$$

$$C_Y = \frac{Y}{\frac{1}{2}\rho V^2 S} = C_{Y_\beta}\beta + C_{Y_{\delta_{\mathrm{a}}}}\delta_{\mathrm{a}} + C_{Y_{\delta_{\mathrm{r}}}}\delta_{\mathrm{r}} + \Big(C_{Y_{\dot{\beta}}}\dot{\beta} + C_{Y_p}\,p + C_{Y_r}\,r\Big)\frac{b}{2V} \tag{17.18}$$

Nelle (7.53)-(7.56)-(17.18) le grandezze (p, q, r) vanno interpretate in generale come le componenti di $\boldsymbol{\Omega}_{\mathrm{B}}$ nel sistema di assi in cui sono espresse le equazioni del moto. Per il moto in esame è opportuno operare le sostituzioni

$$p \longleftarrow p^{\mathrm{A}} = \Omega_{\mathrm{B},x_{\mathrm{A}}}\,, \qquad q \longleftarrow q^{\mathrm{A}} = \Omega_{\mathrm{B},y_{\mathrm{A}}}\,, \qquad r \longleftarrow r^{\mathrm{A}} = \Omega_{\mathrm{B},z_{\mathrm{A}}} \tag{17.19}$$

che in base alle (17.12) forniscono

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Figure 3: Aerospace engineering textbook.

http://wpage.unina.it/agodemar/DSV-DQV/DSV-DQV_Quaderno_17.pdf

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Choose effective informative titles (figure and table captions). Possibly, make them brief and informative at the same time.

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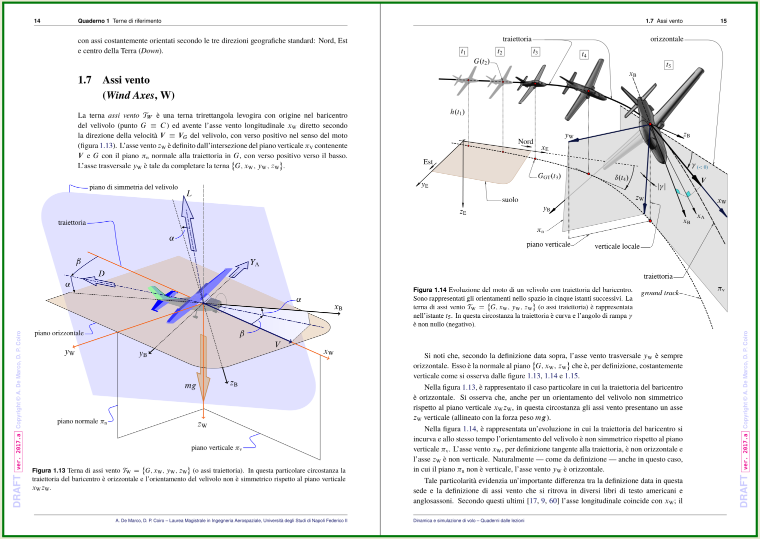

14 **Quaderno 1** Terne di riferimento

con assi costantemente orientati secondo le tre direzioni geografiche standard: Nord, Est e centro della Terra (*Down*).

1.7 Assi vento (*Wind Axes*, W)

La terna *assi vento* $\mathcal{T}_W$ è una terna trirettangola levogira con origine nel baricentro del velivolo (punto $G \equiv C$) ed avente l'asse vento longitudinale x_W diretto secondo la direzione della velocità $\boldsymbol{V} \equiv \boldsymbol{V}_G$ del velivolo, con verso positivo nel senso del moto (figura 1.13). L'asse vento z_W è definito dall'intersezione del piano verticale π_V contenente $\boldsymbol{V}$ e G con il piano π_n normale alla traiettoria in G, con verso positivo verso il basso. L'asse trasversale y_W è tale da completare la terna $\{G, x_W, y_W, z_W\}$.

Figura 1.13 Terna di assi vento $\mathcal{T}_W = \{G, x_W, y_W, z_W\}$ (o assi traiettoria). In questa particolare circostanza la traiettoria del baricentro è orizzontale e l'orientamento del velivolo non è simmetrico rispetto al piano verticale $x_W z_W$.

A. De Marco, D. P. Coiro – Laurea Magistrale in Ingegneria Aerospaziale, Università degli Studi di Napoli Federico II

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1.7 Assi vento 15

Figura 1.14 Evoluzione del moto di un velivolo con traiettoria del baricentro. Sono rappresentati gli orientamenti nello spazio in cinque istanti successivi. La terna di assi vento $\mathcal{T}_W = \{G, x_W, y_W, z_W\}$ (o assi traiettoria) è rappresentata nell'istante t_5. In questa circostanza la traiettoria è curva e l'angolo di rampa γ è non nullo (negativo).

Si noti che, secondo la definizione data sopra, l'asse vento trasversale y_W è sempre orizzontale. Esso è la normale al piano $\{G, x_W, z_W\}$ che è, per definizione, costantemente verticale come si osserva dalle figure 1.13, 1.14 e 1.15.

Nella figura 1.13, è rappresentato il caso particolare in cui la traiettoria del baricentro è orizzontale. Si osserva che, anche per un orientamento del velivolo non simmetrico rispetto al piano verticale $x_W z_W$, in questa circostanza gli assi vento presentano un asse z_W verticale (allineato con la forza peso $m\boldsymbol{g}$).

Nella figura 1.14, è rappresentata un'evoluzione in cui la traiettoria del baricentro si incurva e allo stesso tempo l'orientamento del velivolo è non simmetrico rispetto al piano verticale π_v. L'asse vento x_W, per definizione tangente alla traiettoria, è non orizzontale e l'asse z_W è non verticale. Naturalmente — come da definizione — anche in questo caso, in cui il piano π_n non è verticale, l'asse vento y_W è orizzontale.

Tale particolarità evidenzia un'importante differenza tra la definizione data in questa sede e la definizione di assi vento che si ritrova in diversi libri di testo americani e anglosassoni. Secondo questi ultimi [17, 9, 60] l'asse longitudinale coincide con x_W; il

Dinamica e simulazione di volo – Quaderni dalle lezioni

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Figure 4: Aerospace engineering textbook.

http://wpage.unina.it/agodemar/DSV-DQV/DSV-DQV_Quaderno_1.pdf

Inkscape

http://www.inkscape.org

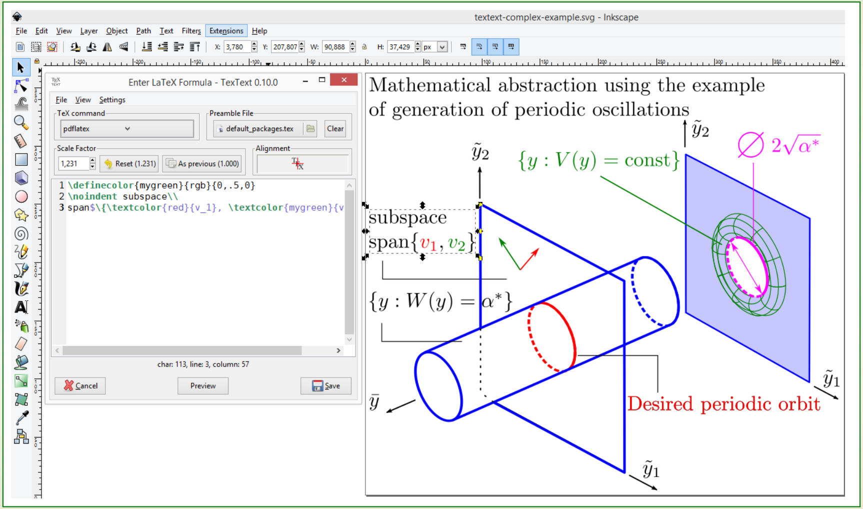
Inkscape is an ***open source*** and well-supported ***vector graphics/SVG editor*** available for all major operating systems.

Provides effective LaTeX-related capabilities, e. g. the TexText Python-based plugin extension.

https://textext.github.io/textext

TexText provides the possibility to ***add and re-edit (multi-line) LaTeX/XeLaTeX/LuaLaTeX generated SVG elements to a drawing***.

Inkscape



textext-complex-example.svg - Inkscape

Enter LaTeX Formula - TexText 0.10.0

TeX command: pdflatex

Preamble File: default_packages.tex

Scale Factor: 1,231

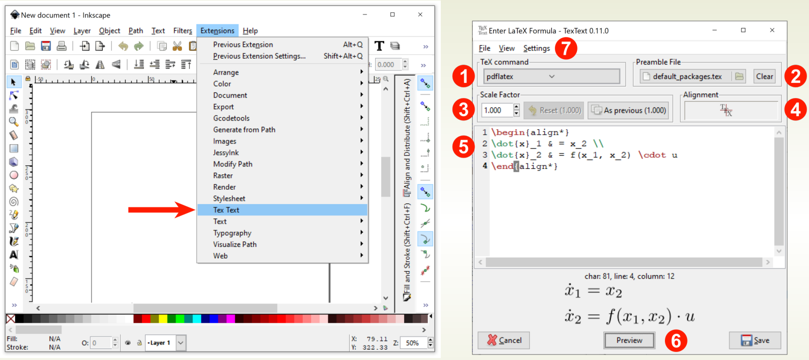
X: 3,780 Y: 207,807 W: 90,888 H: 37,429 px

```
\definecolor{mygreen}{rgb}{0,.5,0}
\noindent subspace\\
span$\{\textcolor{red}{v_1}, \textcolor{mygreen}{v
```

char: 113, line: 3, column: 57

Figure 5: A screenshot of Inkscape with TexText extension in use.

Inkscape



TeX command: pdflatex

Preamble File: default_packages.tex Clear

Scale Factor: 1.000 Reset (1.000) As previous (1.000)

Alignment

```
\begin{align*}
\dot{x}_1 & = x_2 \\
\dot{x}_2 & = f(x_1, x_2) \cdot u
\end{align*}
```

char: 81, line: 4, column: 12

$$\dot{x}_1 = x_2$$

$$\dot{x}_2 = f(x_1, x_2) \cdot u$$

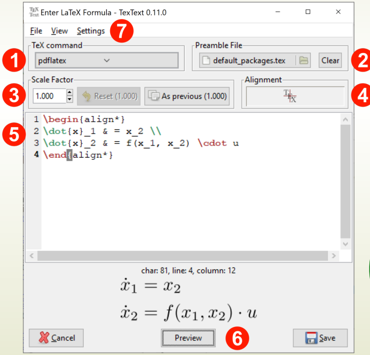
(a) Selecting TexText from Inkscape Extensions menu.

(b) The TexText dialog window.

Figure 6: Using TexText extension plugin in Inkscape.

Inkscape

```latex
% default_packages.tex
\usepackage{amsmath,amsthm,amssymb,
    amsfonts}
\usepackage{color}
```



Enter LaTeX Formula - TexText 0.11.0

- TeX command: pdflatex
- Preamble File: default_packages.tex
- Scale Factor: 1.000

```latex
\begin{align*}
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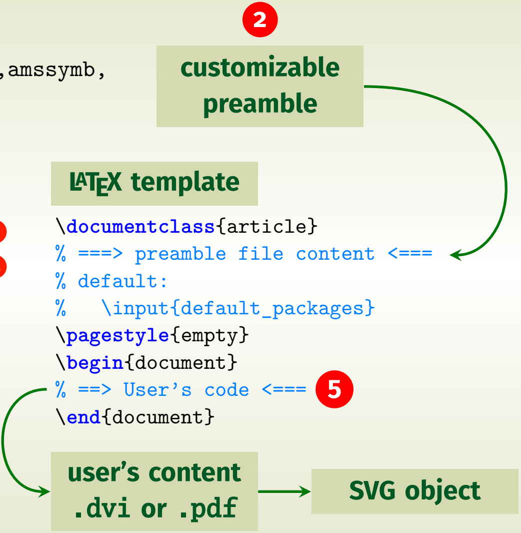
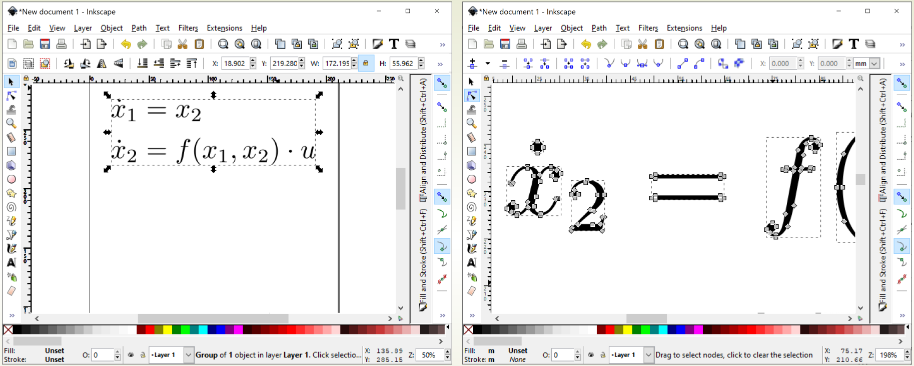


LaTeX template

```latex
\documentclass{article}
% ===> preamble file content <===
% default:
%   \input{default_packages}
\pagestyle{empty}
\begin{document}
% ==> User's code <===
\end{document}
```

Inkscape


*New document 1 - Inkscape
File Edit View Layer Object Path Text Filters Extensions Help
Fill and Stroke (Shift+Ctrl+F)
Align and Distribute (Shift+Ctrl+A)
*New document 1 - Inkscape
File Edit View Layer Object Path Text Filters Extensions Help
Fill and Stroke (Shift+Ctrl+F)
Align and Distribute (Shift+Ctrl+A)

$$\dot{x}_1 = x_2$$
$$\dot{x}_2 = f(x_1, x_2) \cdot u$$

X: 18.902 Y: 219.280 W: 172.195 H: 55.962

Fill: Unset Stroke: Unset O: 0 ·Layer 1 Group of 1 object in layer **Layer 1**. Click selectio... X: 135.89 Y: 285.15 Z: 50%

X: 0.000 Y: 0.000 mm

Fill: m Unset Stroke: m *None* O: 0 ·Layer 1 Drag to select nodes, click to clear the selection X: 75.17 Y: 210.66 Z: 198%

Figure 7: SVG element resulting from user's input compilation (see Figure 6b).

The final SVG object is re-editable via the* `TexText` *dialog!

Inkscape

Demo

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- The package `tikz`

Data plots with package `pgfplots`

Making drawings with code

A completely different paradigm.

No pseudo-synchronous visual tools.

Similar to the asynchronous typesetting workflow.

The native environment picture

```
% in preamble
\usepackage{pict2e}
% ...
\begin{picture}(120 ,80)
  \put(30,30){\circle*{3}}
  \put(30,33){\makebox(0,0)[br]{$A$}}
  \put(90,43){\circle*{3}}
  \put(88,47){\makebox(0,0)[bl]{$B$}}
  \linethickness{1.2pt}
  \Line(30,30)(90,43)
  \put(10,10){\vector(1,0){100}}
  \put(110,14){\makebox(0,0)[b]{$x$}}
  \put(10,10){\vector(0,1){60}}
  \put(14,70){\makebox(0,0)[l]{$y$}}
  % dashed box
  \put(0,0){\dashbox{5}(120,80){}}
\end{picture}
```

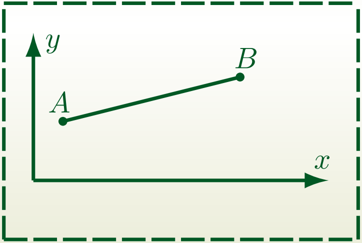


Figure 8: A drawing made with the standard picture environment enhanced by the pict2e package.

Drawing with pstricks

```
% arara: latex
% arara: dvips
% arara: ps2pdf
\documentclass[%
  border={0.6cm 0.6cm 0.6cm 0.6cm}% l b r t
  ]{standalone}
\usepackage[pdf]{pstricks}
\usepackage{pst-all}
\usepackage{pstricks-add}

\begin{document}
\begin{pspicture}(-1,0)(1,5)
  \psgrid[griddots=10,subgriddots=3,
    gridlabelcolor=blue](-1,0)(1,5)
  \psdots[linecolor=red,dotsize=10pt]
    (0,5)(-1,3)(1,2)(0.5,1)
  \rput(0,5){Center,Middle}
  \rput[bl](-1,3){%
    $\underbrace{\text{bottom,left}}_{\text{Really!}}$}
  \rput[Br](1,2){%
    $\underbrace{\text{Baseline,right}}_{\text{Really!}}$}
  \rput[tr]{45}(0.5,1){
    \parbox{5cm}{\flushright Rotated\\ by $45^{\circ}$}
  }
\end{pspicture}
\end{document}
```

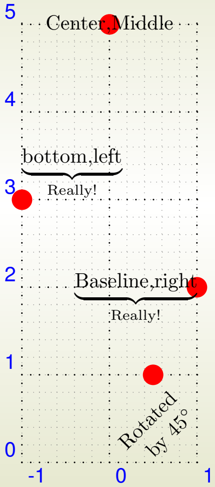


Figure 9: Placing whatever, wherever in a pspicture environment.

Drawing with packages pgf and tikz

Then whe have **pgf** and **tikz** by Till Tantau ...

https://www.ctan.org/pkg/pgf

http://texdoc.net/texmf-dist/doc/generic/pgf/pgfmanual.pdf

https://pgf-tikz.github.io/ (manual on the web)

Drawing with packages `pgf` and `tikz`

The name ***PGF*** means ***PORTABLE GRAPHICS FORMAT***.

It is a package for creating ***inline graphics***: defines a number of TEX commands that can draw graphics within the typesetting process.

Graphics objects are put into boxes and treated as normal items to be taken care of by the LATEX output routine.

The package `pgf` exposes a ***frontend layer***, i. e. a set of commands or a special syntax that makes using the functionalities implemented by basic layer easier.

This frontend is what is called ***TIKZ***, the LATEX package `tikz` that incorporates `pgf`.

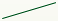
The name ***TIKZ*** is an acronym of ***TIKZ IST KEIN ZEICHENPROGRAMM*** (German for ‘tikz is not a drawing program’).

Drawing with tikz

In preamble: `\usepackage{tikz}`

The package provides the command `\tikz` as in the following examples.

```
\tikz \draw (0pt,0pt) -- (20pt,6pt);
```

yields the line , or

```
\tikz \fill[color=orange] (1ex,1ex) circle(1ex);
```

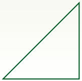
yields the orange circle .

The argument passed to `\tikz` is a semicolon-terminated string.

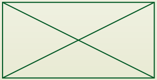
The tikzpicture environment

More elaborate drawings are embedded into the environment tikzpicture:

```
\begin{tikzpicture}
  \draw (0,0) -- (1,0) -- (1,1)
    -- cycle;
\end{tikzpicture}
```



```
\begin{tikzpicture}
  \draw (0,0) rectangle (2,1);
  \draw (0,0) -- (2,1);
  \draw (0,1) -- (2,0.0);
\end{tikzpicture}
```



The `tikzpicture` environment

A `tikzpicture` can be used *inline* with the running text of a paragraph, like any other box object:

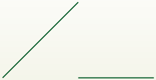
```
The following draws a
$0.4 \times 0.2$ crossed rectangle:
\begin{tikzpicture}
  \draw (0.0,0.0) rectangle
    (0.4,0.2);
  \draw (0.0,0.0) -- (0.4,0.2);
  \draw (0.0,0.2) -- (0.4,0.0);
\end{tikzpicture}\,.
```

The following draws a 0.4×0.2 crossed rectangle: ⊠.

Path extensions operations

Inside a `tikzpicture` environment ***everything is drawn by starting a path and by extending the path***. Paths are constructed using the `\path` command.

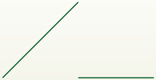
```
\begin{tikzpicture}
  \path[draw] (0,0) -- (1,1);
  \path[draw] (1,0) -- (2,0);
\end{tikzpicture}
```



Path extensions operations

Inside a `tikzpicture` environment ***everything is drawn by starting a path and by extending the path***. Paths are constructed using the `\path` command.

```
\begin{tikzpicture}
  \path[draw] (0,0) -- (1,1);
  \path[draw] (1,0) -- (2,0);
\end{tikzpicture}
```



directive or option

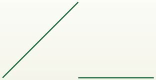
Path extensions operations

Inside a `tikzpicture` environment ***everything is drawn by starting a path and by extending the path***. Paths are constructed using the `\path` command.

```
\begin{tikzpicture}
  \path[draw] (0,0) -- (1,1);
  \path[draw] (1,0) -- (2,0);
\end{tikzpicture}
```

directive or option

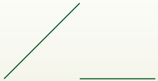
starting coordinate

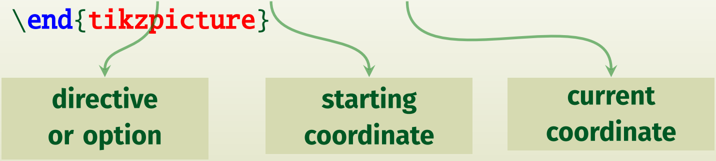


Path extensions operations

Inside a `tikzpicture` environment ***everything is drawn by starting a path and by extending the path***. Paths are constructed using the `\path` command.

```
\begin{tikzpicture}
  \path[draw] (0,0) -- (1,1);
  \path[draw] (1,0) -- (2,0);
\end{tikzpicture}
```





directive or option

starting coordinate

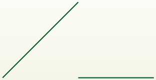
current coordinate

Path extensions operations

Inside a `tikzpicture` environment ***everything is drawn by starting a path and by extending the path***. Paths are constructed using the `\path` command.

type of extension

```
\begin{tikzpicture}
  \path[draw] (0,0) -- (1,1);
  \path[draw] (1,0) -- (2,0);
\end{tikzpicture}
```



directive or option

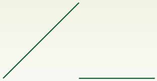
starting coordinate

current coordinate

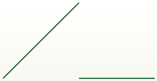
Line-to and *move-to* operations

Command \draw stands for \path[draw]:

```
\path[draw] (0,0) -- (1,1);
\path[draw] (1,0) -- (2,0);
```

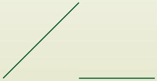


```
\draw (0,0) -- (1,1);
\draw (1,0) -- (2,0);
```



Multiple paths can be traced with one single command:

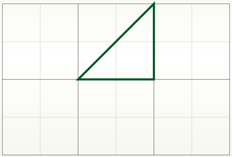
```
\draw (0,0) -- (1,1)
  % move-to operation
  (1,0) -- (2,0);
```



The *grid* and *cycle* operations

A **grid** is a path extension operation between two coordinates, much like a line (**--**):

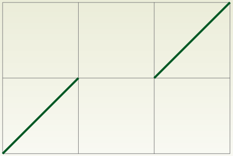
```
% fine, thin grid
\draw[line width=0.1pt,gray!30,step=5mm]
  (0,0) grid (3,2);
% coarse, thicker grid
\draw[help lines]
  (0,0) grid (3,2);
% a thick, closed path
\draw[thick] (1,1) -- (2,2) -- (2,1)
  -- cycle;
```



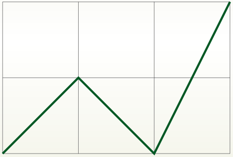
The **cycle** operation closes a path connecting the current point with the initial point on the path.

More *line-to* and *move-to* operations

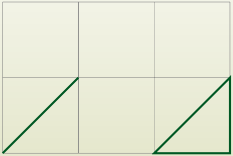
```
\draw[help lines] (0,0) grid (3,2);
\draw[thick] (0,0) -- (1,1)
  % then move-to
  (2,1) -- (3,2);
```



```
\draw[help lines] (0,0) grid (3,2);
\draw[thick] (0,0) -- (1,1) --
  (2,0) -- (3,2);
```

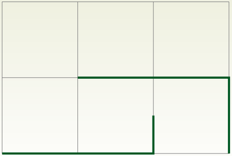


```
\draw[help lines] (0,0) grid (3,2);
\draw[thick] (0,0) -- (1,1)
  % then move-to
  (2,0) -- (3,0) --
  (3,1) -- cycle;
```

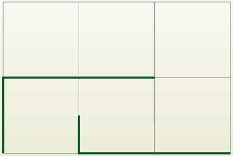


More *line-to* operations

```
\draw[thick] (0.0,0.0) -| (2.0,0.5)
  (1.0,1.0) -| (3.0,0.0);
```

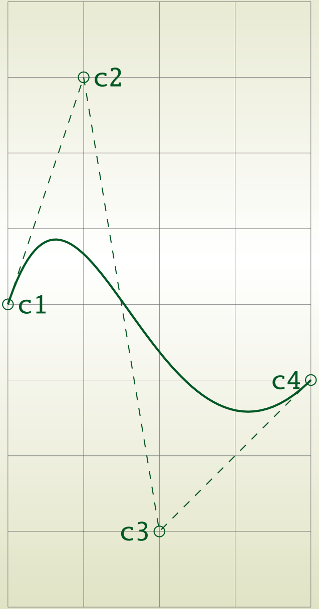


```
\draw[thick] (0.0,0.0) |- (2.0,1.0)
  (1.0,0.5) |- (3.0,0.0);
```



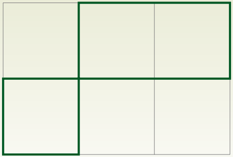
The *curve-to* operation

```
% the supporting grid
\draw[help lines] (-2,-4) grid (2,4);
% define labels (nodes)
\path (-2, 0) coordinate(c1)
  (-1, 3) coordinate(c2)
  ( 0,-3) coordinate(c3)
  ( 2,-1) coordinate(c4);
% segments connecting nodes
\draw[dashed] (c1) -- (c2) -- (c3) -- (c4);
% control points
\draw (c1) circle (2pt)
  (c2) circle (2pt)
  (c3) circle (2pt)
  (c4) circle (2pt);
% the Bézier curve
\draw[thick] (c1) .. controls (c2)
  \and (c3) .. (c4);
% text labels
\path
  (c1) node[anchor=west] {\texttt{c1}}
  (c2) node[anchor=west] {\texttt{c2}}
  (c3) node[anchor=east] {\texttt{c3}}
  (c4) node[anchor=east] {\texttt{c4}};
```

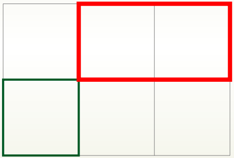


The *rectangle* and *circle* operations

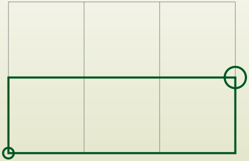
```
\draw[thick] (0,0) rectangle (1,1)
  rectangle (3,2);
```



```
\draw[thick] (0,0) rectangle (1,1);
\draw[ultra thick,red] (1,1)
  rectangle (3,2);
```

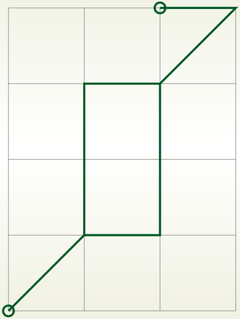


```
\draw[thick] (0,0) circle (2pt)
  rectangle (3,1)
  circle (4pt);
```



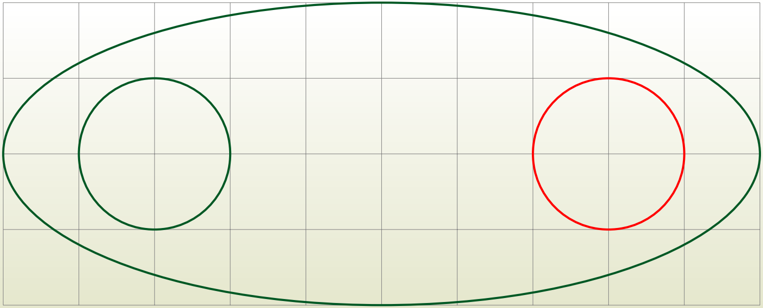
Multiple path extensions

```
\begin{tikzpicture}
  \draw[help lines] (0,0) grid (3,4);
  \draw[thick] (0,0) circle (2pt)
    -- (1,1) rectangle (2,3)
    -- (3,4)
    -- (2,4) circle (2pt);
\end{tikzpicture}
```



The *ellipse* operation

```
\draw[help lines] (0,0) grid (10,4);
\draw (2,2) ellipse (1cm and 1cm)
  (3,2) ellipse (3cm and 2cm);
\draw[red] (8,2) ellipse (1cm and 1cm);
```



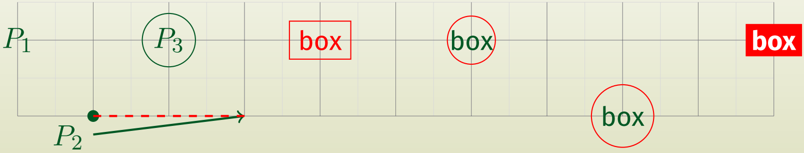
The *node* operation

You can add text, math, and other material to paths with the ***node path extension operation***.

The node operation

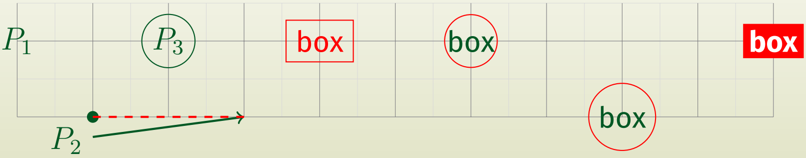
- places a given textual content at the current position;
- the current position becomes a node in the path;
- a label (variable name) can be associated to the node;
- named nodes can be used in further drawing operations;

Each node added to a path has an ***outer shape***. The outer shape is only drawn if `draw` is part of the options. ***The default node shape is a rectangle***.

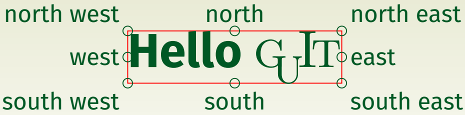


The *node* operation

```
% in preamble: \usetikzlibrary{calc,positioning}
\path[draw] (0,1) node (p1) [draw=none] {$P_1$};
\path[draw,fill] (1,0) circle (2pt) node (p2) [anchor=north east] {$P_2$};
\path (2,1) coordinate (p3);
\path[draw] (p3) circle (10pt) node[draw=none] {$P_3$};
\path (3,0) coordinate (p4);
\draw[thick,->] (p2) -- (p4);
\draw[thick,dashed,red] (p2.north east) -- (p4);
\path (4,1) coordinate (p5);
\path[draw=none] (p5) circle (8pt) node[draw,red] {box};
\node [right=2.0cm of p5, anchor=center,
  inner sep=0pt, shape=circle, draw=red] (p6) {box};
\node[below right=1.0cm and 2.0cm of p6.center, anchor=center,
  inner sep=2pt, shape=circle, draw=red] (p7) {box};
\node [above right=1.0cm and 2.0cm of p7.center, anchor=center, inner
     sep=2pt, draw=red, fill=red, fill=white] (p7) {\textbf{box}};
```



Placing textual labels



```
\begin{tikzpicture}
  \draw (0,0)
    node (hello)
      [scale=2.0,
      inner sep=0pt,outer sep=0pt,
      draw=red]
      {\fbox{\textbf{Hello \GuIT}}};
  \draw (hello.north east) circle (2pt) node[anchor=south west] {north east};
  \draw (hello.north     ) circle (2pt) node[anchor=south     ] {north};
  \draw (hello.north west) circle (2pt) node[anchor=south east] {north west};
  \draw (hello.west      ) circle (2pt) node[anchor=east      ] {west};
  \draw (hello.south west) circle (2pt) node[anchor=north east] {south west};
  \draw (hello.south     ) circle (2pt) node[anchor=north     ] {south};
  \draw (hello.south east) circle (2pt) node[anchor=north west] {south east};
  \draw (hello.east      ) circle (2pt) node[anchor=west      ] {east};
\end{tikzpicture}
```

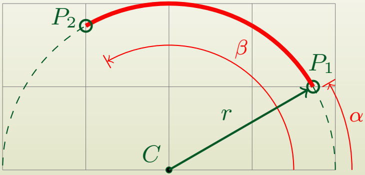
The *arc* operation

The arc operation adds an arc to the path.

- The arc starts at the current point, P_1. The user supplies two angles, α and β, and a radius r.
- The centre of the circle, C, is determined by the equation

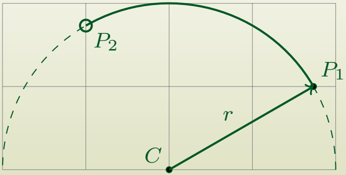
  $$P_1 = C + (r\cos\alpha, r\sin\alpha)$$

  The end point of the arc is given by $P_2 = C + (r\cos\beta, r\sin\beta)$.
- The arc is drawn in counterclockwise direction from the start point to the end point, which becomes the new current coordinate of the path.



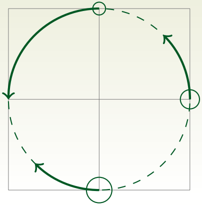
The *arc* operation

```
\draw[dashed] (4,0) coordinate (p0) arc (0:180:2cm); % ($\alpha, \beta, r$)

\draw[fill=black] (2,0) coordinate (c) % $\longleftarrow C$
  circle (1pt) node[anchor=south east] {$C$};

\path (p0) arc (0:30:2cm) % ($\alpha, \beta, r$), no arc drawn
  coordinate (p30); % $\longleftarrow P_1$

\draw[fill=black] (p30) circle (1pt) node[anchor=south west] {$P_1$};

\draw[thick] (p30) arc (30:120:2cm) % ($\alpha, \beta, r$)
  coordinate (p120) % $\longleftarrow P_2$
  circle (2pt) node[anchor=north west] {$P_2$};

\draw[->,thick] (c) -- node[anchor=south east] {$r$} (p30); % $\longleftarrow \vec{r}$
```

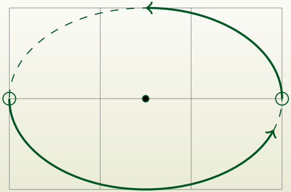


More *arc* operations

```
\draw[dashed] (1,1) circle (1cm);
\draw (1,2) coordinate (a) circle (2pt)
  (2,1) coordinate (b) circle (3pt)
  (1,0) coordinate (c) circle (4pt);
\draw[->,thick] (a) arc (90:180:1cm);
\draw[->,thick] (b) arc (0:45:1cm);
\draw[->,thick] (c) arc (270:225:1cm);
```



```
\draw[dashed] (1.5,0) circle (1.5cm and 1cm);
\draw[fill=black] (1.5,0) coordinate (c)
  circle (1pt);
\draw (3,0) coordinate (a) circle (2pt);
\draw (0,0) coordinate (b) circle (2pt);
\draw[->,thick] (a) arc (0:90:1.5cm and 1cm);
\draw[->,thick] (b) arc (180:340:1.5cm and 1cm);
```



Drawing with `tikz`

What else?

- More actions on paths, e.g. line widths, dash patterns, coloring, filling, shading.
- predefined styles of graphic elements and their customizations.
- Available coordinate systems and advanced coordinate calculations.

Please have a look at the article on ArsTEXnica for more details on `tikz`:

De Marco, A. "Graphics for LATEX users".
ArsTEXnica 28 (October 2019), pp. 64–100.

All `tikz` examples given in the article are viewable on Overleaf:
`https://www.overleaf.com/read/mgskyfdpttzt`

Outline

General guidelines on illustration design

Drawing with LaTeX-aware software

- Using `Inkscape` + `TexText` extension

Drawing with natively available LaTeX environments/packages

- The standard environment `picture`
- The package `pstricks` (PostScript)
- The package `tikz`

Data plots with package `pgfplots`

Plotting data with pgfplots

The package **pgfplots** is built on top of pgf and is designed to draw graphs in a variety of formats, with a consistentand professional look and feel.

The package also allows to import data stored in files in tabular format via the package **pgfplotstable**.

As is usual with the pgf family, their manuals are impressive.

https://www.ctan.org/pkg/pgfplots
http://texdoc.net/texmf-dist/doc/latex/pgfplots/pgfplots.pdf
http://texdoc.net/texmf-dist/doc/latex/pgfplots/pgfplotstable.pdf

The axis environment

The workhorse of the pgfplots package is an environment called **axis**, which may ***define one or several plots*** (2D and 3D).

Each plot is drawn with the command \addplot.

The axis environment is used inside a tikzpicture environment.

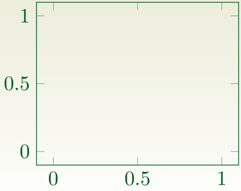
Typically, one or more plots are created in LaTeX as follows:

```
% in preamble
\usepackage{pgfplots}% loads tikz
...
\begin{tikzpicture}
   \begin{axis}[⟨graphic options⟩]
   ...
   ⟨pgfplots or tikz commands⟩
   ...
   \end{axis}
\end{tikzpicture}
```

The `axis` environment

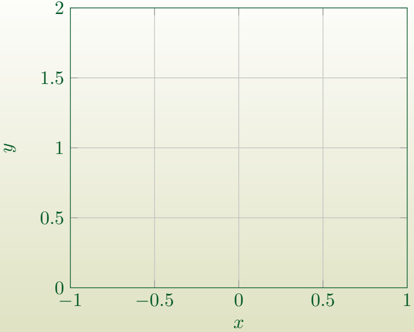
The simplest possible graph with `pgfplots`:

```
\begin{tikzpicture}
   \begin{axis}
   \end{axis}
\end{tikzpicture}
```



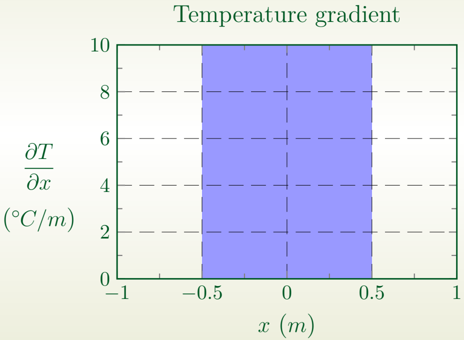
An empty `axis` environment, with customized formatting options:

```
\begin{axis}[
  xmin = -1, xmax = 1,
  ymin =  0, ymax = 2,
  grid = major,
  xlabel = $x$, ylabel = $y$
]
\end{axis}
```



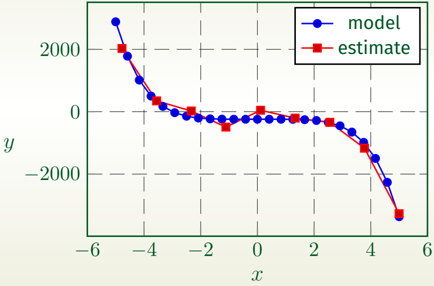
The `axis` environment

```
\begin{axis}[
  xmin = -1, xmax = 1,
  ymin = 0, ymax = 10,
  xtick = {-1,-0.5,...,1},
  ytick = {0,2,...,10},
  minor x tick num = 1,
  minor y tick num = 1,
  grid = major,
  xlabel ={$x$ (\si{\meter})},
  ylabel ={
    \parbox{2cm}{%
      \centering
      $\dfrac{\partial T}{\partial x}$
      \\[0.7em]
      \centering
      (\si{\celsius/\meter})
    }
  },
  title = {Temperature gradient},
  axis on top = true]
  % a basic tikz drawing command
  \fill[blue!40]
    (axis cs: -0.5, 0) -- (axis cs:  0.5, 0) --
    (axis cs:  0.5,10) -- (axis cs: -0.5,10) --
    cycle;
\end{axis}
```



The \addplot command

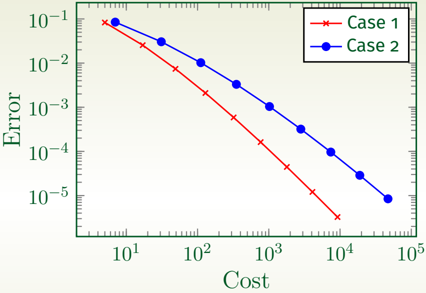
```
\begin{axis}[
  grid = major,
  xlabel = {$x$},
  ylabel = {$y$},
  y tick label style = {
    /pgf/number format/.cd,
    set thousands separator={}
  }]

  \addplot {-x^5 - 242};
  \addlegendentry{model}

  \addplot coordinates {
          (-4.77778,  2027.60977)
          (-3.55556,   347.84069)
          (-2.33333,    22.58953)
          (-1.11111,  -493.50066)
          ( 0.11111,    46.66082)
          ( 1.33333,  -205.56286)
          ( 2.55556,  -341.40638)
          ( 3.77778, -1169.24780)
          ( 5.00000, -3269.56775)
  };
  \addlegendentry{estimate}

\end{axis}
```



The \addplot command

Reading tabular data from file:

```
% in preamble
\usepackage{filecontents}
\begin{filecontents*}{data1.txt}
Level   Cost       Error
1          7 8.47178381e-02
2         31 3.04409349e-02
3        111 1.02214539e-02
4        351 3.30346265e-03
5       1023 1.03886535e-03
6       2815 3.19646457e-04
7       7423 9.65789766e-05
8      18943 2.87339125e-05
9      47103 8.43749881e-06
\end{filecontents*}
% ...
\begin{tikzpicture}
  \begin{loglogaxis}[xlabel={Cost}, ylabel={Error}]
  \addplot[color=red, mark=x] coordinates {
  (5,    8.31160034e-02)
  (17,   2.54685628e-02)
  (49,   7.40715288e-03)
  % ...
  (9217, 3.26101452e-06)
};
\addplot[color=blue, mark=*] table[x=Cost, y=Error] {data1.txt};
\legend{Case 1,Case 2}
\end{loglogaxis}
\end{tikzpicture}
```



Plotting data with pgfplots

What else?

- Data column manipulation with `pgfplotstable`.
- Style customizations of graphic elements.
- Available coordinate systems and advanced coordinate calculations. 3D plots.
- Exporting `pgfplots` sources from other data plotting tools.

Please have a look at the article on ArsTEXnica for more details on `pgfplots`:

- *De Marco, A., "Graphics for LATEX users". ArsTEXnica 28 (October 2019), pp. 64–100.*
- *De Marco, A. and Giacomelli, R., "Creare grafici con pgfplots". ArsTEXnica 13 (October 2011), pp. 9–35.*

Conclusions

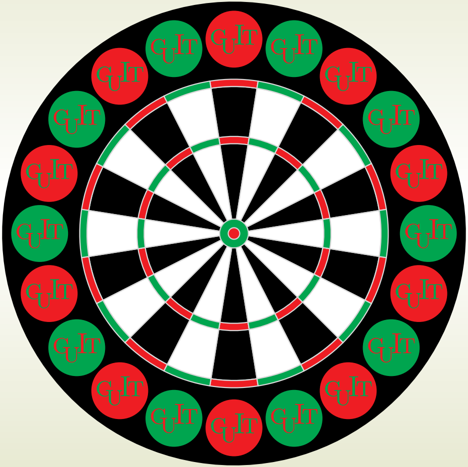
We have seen the most common scenarios encountered by LaTeX users when they face the problem of producing quality graphics.

In cases of diagrams, pictures and more or less complicated illustrations the two approaches based on package `tikz` and on the `Inkscape` graphics vector software have been presented.

Examples of scientific plots with the package `pgfplots`.

Thank you …

Questions?



http://texample.net/tikz/examples/dartboard/