How to make nice looking plots with TikZ/pgfplots

Anders Mannesson

May 30, 2016

This is a description of the techniques I used for making the nice (to some at least) graphics found in my thesis. All files for generating the data files in Matlab and the Latex code is available to download and to play around with. The documentation covers a Matlab-to-pgfplots work flow and how to make boxplots that can be customized.

1   Matlab to csv-files

The Matlab function `saveMatrix2File` is a wrapper function for the internal Matlab function `dlmwrite`. The internal function saves a matrix as a delimiter separated ASCII file, suitable for being used in TikZ/pgfplots in Latex. The drawback with the internal function it lacks the possibility to add titles for the columns which makes your life in pgfplots easier. This is solved with `saveMatrix2File`.

To work with boxplots in TikZ/pgfplots, the data from the boxplot in Matlab is extracted using a script called `boxExtract.m`. Two files are produced, one which contains the median and the whiskers, and another file which contains all the outliers.

1.1   Listing `saveMatrix2File.m`

```matlab
function saveMatrix2File(fileName,data,prec,columnName)
% Saves data to a delimiter separated file
% The data to be save must be ordered columnwise in a matrix
% There is an option for adding names for the columns in the output file
%
% fileName is the output filename
% data is the matrix to be saved
% prec controls the precision
% columnName contains the strings for column names, if omitted no column names will be given

    fid = fopen(fileName,'w');
    if nargin == 4
        for n = 1:length(columnName)-1
            fprintf(fid,strcat(char(columnName(n)),'\t'));
        end
        fprintf(fid,strcat(char(columnName(end)),'\n'));
        fclose(fid);
    end

    % write the data to file
    dlmwrite(fileName, data, 'delimiter','\t','-append', 'precision',prec)

end
```

1.2   Listing `saveBoxdata2File.m`

```matlab
% saveBoxdata2File(x,h,fileName)
% saves boxplot data in a format that can be used in TikZ/pgfplots
% x: the x values
% h: the boxplot handle
% filename: the output filename
```

```matlab
function saveBoxdata2File(xV,h,fileName)

    h1 = findobj(h,'tag','Median');
    xdata = get(h1,'XData');
    ydata = get(h1,'YData');

    N = length(xdata);
    X = zeros(N,6);

    % extract median
    for n = 1:N
        X(n,1) = xV(mean(xdata{n}));
        X(n,2) = mean(ydata{n});
    end

    % extract lower whisker
    h1 = findobj(h,'tag','Lower Whisker');
    ydata = get(h1,'YData');
    X(:,[6,4]) = cell2mat(ydata);

    % extract upper whisker
    h1 = findobj(h,'tag','Upper Whisker');
    ydata = get(h1,'YData');
    X(:,[3,5]) = cell2mat(ydata);

    % extract outliers
    h1 = findobj(h,'tag','Outliers');
    outliersY = get(h1,'YData');
    outliersX = get(h1,'XData');
    Y = [];
    for n = 1:N
        if ~isnan(outliersX{n})
            Y = [Y;xV(outliersX{n})' outliersY{n}'];
        end
    end

    % the box
    cNames = {'index','median','lower wisker','lower percentile',...
        'upper percentile','upper whisker'};
    saveMatrix2File(fileName,X,4,cNames);

    % the outliers
    oFile = strcat(fileName(1:end-4),'_outliers.csv');
    saveMatrix2File(oFile,Y,4,{'index','value'});

end
```

2 Plotting with TikZ/pgfplots

2.1 Working with plot styles

By defining a plot style, you can easily produce plots that will have the same appearance. All properties of a plot can be customized to your taste but below there are examples that covers some of the properties. The plot styles can preferably be placed in a separate file and added to you Latex document with the input command before the plot is created but after the pgfplots package is added.

The short label style defined below is suitable if the y-axis label is short while the long label style is for long y-axis labels.

The built in box plot environment in pgfplots does not let you control anything. Below is a

pgfplot style which I have modified so you can set the color of the lines, the width of the boxes etc.

2.1.1 Listing `pgfplotsyle.tex`

```
% define a plot style called 'generalplot'
\pgfplotsset{generalplot/.style={
/pgf/number format/1000 sep={},
axis line style={thick,->},
tick style={black,thin},
major tick length={4pt},
tick align={outside},
tick label style={font=\small},
label style={font=\small},
title style={font=\small},
legend style = {font=\small,draw=none,fill=white,cells={align=left}},
every axis plot/.append style={line width = 1pt,mark size=1.75pt},
every axis x label/.append style={at={(ticklabel* cs:1)},anchor=north east},
}}


% define another plot style which in inherits generalplot
\pgfplotsset{arrowplotShortLabel/.style={
generalplot,
every axis y label/.append style={at={(ticklabel* cs:1)},anchor=north west,rotate=-90},
axis x line*=bottom,
axis y line*=left,
}}


% define another plot style which in inherits generalplot
\pgfplotsset{arrowplotLongLabel/.style={
generalplot,
every axis y label/.append style={at={(ticklabel* cs:1)},anchor=north east},
axis x line*=bottom,
axis y line*=left,
}}
```

2.1.2 Listing `boxplotstyle.tex`

```
\pgfplotsset{box plot width/.initial=1cm,
box plot/.style={
    /pgfplots/.cd,
    black,
    only marks,
    mark=-,
    mark size=\pgfkeysvalueof{/pgfplots/box plot width},
    /pgfplots/error bars/.cd,
    y dir=plus,
    y explicit,
},
box plot box/.style={,
    /pgfplots/error bars/draw error bar/.code 2 args={%
        \draw[line width=1pt]%
        ##1 -- ++(\pgfkeysvalueof{/pgfplots/box plot width},0pt) |- ##2 -- %
        ++(-\pgfkeysvalueof{/pgfplots/box plot width},0pt) |- ##1;
    },
    /pgfplots/table/.cd,
    y index=2,
    y error expr={\thisrowno{3}-\thisrowno{2}},
    /pgfplots/box plot
},
```

```
box plot top whisker/.style={line width=1pt,
    /pgfplots/error bars/draw error bar/.code 2 args={%
        \pgfkeysgetvalue{/pgfplots/error bars/error mark}%
        {\pgfplotserrorbarsmark}%
        \pgfkeysgetvalue{/pgfplots/error bars/error mark options}%
        {\pgfplotserrorbarsmarkopts}%
        \path [line width=0.75pt]##1 -- ##2;
    },
/pgfplots/table/.cd,
    y index=4,
    y error expr={\thisrowno{2}-\thisrowno{4}},
    /pgfplots/box plot
},
box plot bottom whisker/.style={line width=1pt,
    /pgfplots/error bars/draw error bar/.code 2 args={%
        \pgfkeysgetvalue{/pgfplots/error bars/error mark}%
        {\pgfplotserrorbarsmark}%
        \pgfkeysgetvalue{/pgfplots/error bars/error mark options}%
        {\pgfplotserrorbarsmarkopts}%
        \path [line width=0.75pt]##1 -- ##2;
    },
/pgfplots/table/.cd,
    y index=5,
    y error expr={\thisrowno{3}-\thisrowno{5}},
    /pgfplots/box plot
},
box plot median/.style={ %
line width=1pt,
/pgfplots/box plot
},
}
```

2.2 Plots

2.2.1 Listing `generateData.m`

```
% generate some data
x = (-1.2:0.1:1.2)';
y1 = 1-x.^2;
y2 = x.^2-1;

cNames = {'myXLabel','y1','y2'};
dataMatrix=[x y1 y2];

saveMatrix2File('myOutputFile.csv',dataMatrix,3,cNames);
```

2.2.2 Listing `shortAxisLabelFigure.tex`

```
\documentclass{standalone}

\usepackage{tikz}
\usepackage{pgfplots}
\usetikzlibrary{narrow}
\tikzset{>=narrow}

\input{pgfplotstyle.tex} % this is the style file from previous section

\begin{document}

\begin{tikzpicture}[trim axis right]
\begin{axis}[%
arrowplotShortLabel,  % here you control which plot style defined above to use
```

```
width=8cm,
height=6cm,
scale only axis,
xmin=-1.25,
xmax=1.2,
ymin=-1,
ymax=1.3,
xtick={-1,-0.5,...,1.0},
ytick={-1,-0.5,...,1},
xlabel={My x-axis label [-]},
ylabel={$y$},
legend entries={$1-x^2$,$x^2-1$},
legend style={at={(1,1)},anchor=north east,legend columns=1},
title= {An example with short y-axis label}
]

\addplot [color=black,style=solid,mark=*,mark repeat = 5,mark phase=1]
table[col sep = tab,x=myXLabel,y=y1] {myOutputFile.csv};

\addplot [color=red,style=solid,mark=triangle*,mark repeat = 5,mark phase=1]
table[col sep = tab,x=myXLabel,y=y2] {myOutputFile.csv};
\end{axis}

\end{tikzpicture}
\end{document}
```
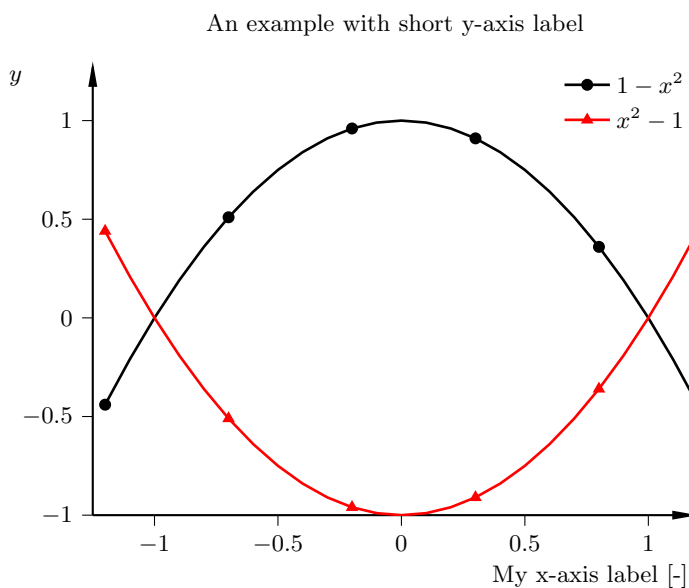

Figure 1: The output figure using short y-axis label in `shortAxisLabelFigure.tex`

2.2.3 Listing `multiplotFigure.tex`

```
\documentclass{standalone}

\usepackage{tikz}
\usepackage{pgfplots}
\usetikzlibrary{narrow,calc}
\tikzset{>=narrow}

\input{pgfplotstyle.tex}

\begin{document}
```

```
\begin{tikzpicture}
\begin{axis}[
name=mainplot,
arrowplotLongLabel,
width=6cm,
height=6cm,
scale only axis,
clip mode=individual,
xmin=-1.25,
xmax=1.25,
xtick={-1,-0.5,...,1},
xlabel={My x-axis label [-]},
ymin=-1.2,
ymax=1.2,
ytick={-1,-0.5,...,1},
ylabel={A really long y-axis label [-]},
title={Main plot}
]

\addplot [color=black,style=solid,mark=*,mark repeat = 5,mark phase=1]
table[col sep = tab,x=myXLabel,y=y1] {myOutputFile.csv};

\addplot [color=red,style=solid,mark=triangle*,mark repeat = 5,mark phase=1]
table[col sep = tab,x=myXLabel,y=y2] {myOutputFile.csv};

% draw a rectangle and lines in main plot
\draw [solid,line width=0.75pt]
(axis cs:-1.1,-0.1)--(axis cs:-1.1,0.1)--(axis cs:-0.9,0.1)--(axis cs:-0.9,-0.1)--cycle;

\draw [dotted,line width=0.75pt] (axis cs:-0.9,-0.1) -- (290,140);
\draw [dotted,line width=0.75pt] (axis cs:-1.1,0.1) -- (290,240);

\draw [solid,line width=0.75pt]
(axis cs:1.1,-0.1)--(axis cs:1.1,0.1)--(axis cs:0.9,0.1)--(axis cs:0.9,-0.1)--cycle;

\draw [dotted,line width=0.75pt] (axis cs:0.9,-0.1) -- (290,0);
\draw [dotted,line width=0.75pt] (axis cs:1.1,0.1) -- (290,100);

\end{axis}

\begin{axis}
[name=plot2,
at={($(mainplot.east)+(1cm,5mm)$)},
anchor=south west,
arrowplotShortLabel,
width=6cm,
height=2.5cm,
scale only axis,
clip mode=individual,
xmin=-1.1,
xmax=-0.88,
xtick={-1.1,-1.05,...,-0.9},
ymin=-0.1,
ymax=0.15,
ytick={-0.1,0,...,0.1},
title={Mini plot 1},
title style={at={(0.5,1)},anchor=north}
]

\addplot [color=black,style=solid]
table[col sep = tab,x=myXLabel,y=y1] {myOutputFile.csv};
```

```
\addplot [color=red,style=solid]
table[col sep = tab,x=myXLabel,y=y2] {myOutputFile.csv};

\end{axis}

\begin{axis}
[name=plot3,
at={($(mainplot.east)+(1cm,-5mm)$)},
anchor=north west,
arrowplotShortLabel,
width=6cm,
height=2.5cm,
scale only axis,
clip mode=individual,
xmin=0.9,
xmax=1.12,
xtick={0.9,0.95,...,1.1},
ymin=-0.1,
ymax=0.15,
ytick={-0.1,0,...,0.1},
title={Mini plot 2},
title style={at={(0.5,1)},anchor=north}
]

\addplot [color=black,style=solid]
table[col sep = tab,x=myXLabel,y=y1] {myOutputFile.csv};

\addplot [color=red,style=solid]
table[col sep = tab,x=myXLabel,y=y2] {myOutputFile.csv};

\end{axis}

\end{tikzpicture}
\end{document}
```
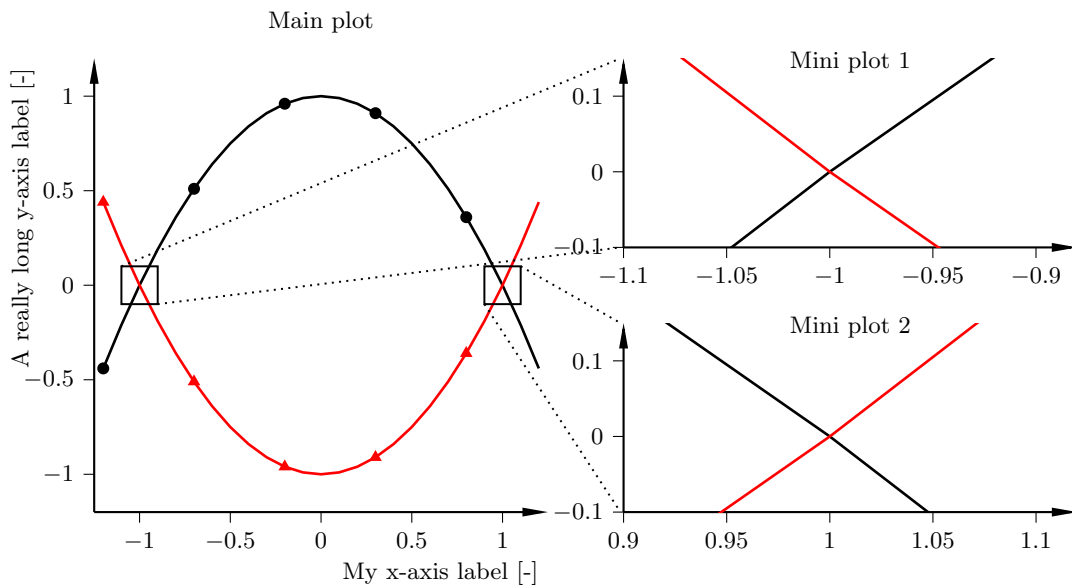

Figure 2: Three axis in the same figure from `multiplotFigure.tex`

2.2.4 Listing generateBoxdata.m

```
% boxplots example
x = (1:5);
X = randn(100,5);
y = bsxfun(@plus,x,X);

h = boxplot(y);

saveBoxdata2File(x,h,'boxTest.csv');
```

2.2.5 Listing boxplotFigure.tex

```
\documentclass{standalone}

\usepackage[cmex10]{amsmath}
\usepackage{tikz}
\usepackage{pgfplots}
\usetikzlibrary{calc,narrow}

\tikzset{>=narrow}

\input{pgfplotstyle.tex}
\input{boxplotstyle.tex}

\begin{document}
\begin{tikzpicture} %[trim axis left, trim axis right]
\begin{axis}[
arrowplotShortLabel,
scale only axis,
box plot width=1em,
width=8cm,
height=6cm,
xtick={0,1,...,5},
xmin=0,
xmax=5.5,
ymin=-2,
ymax=10,
ytick={-2,0,...,8},
xlabel={Time [s]},
ylabel={$y$},
title={My box plot},
title style={at={(0.5,1)}, anchor = center},
]

\addplot [only marks,mark=x,gray] table[col sep=tab,x=index,y=value]
{boxTest_outliers.csv};

\addplot [box plot median] table {boxTest.csv};
\addplot [box plot box] table {boxTest.csv};
\addplot [box plot top whisker] table {boxTest.csv};
\addplot [box plot bottom whisker] table {boxTest.csv};

\end{axis}

\end{tikzpicture}
\end{document}
```
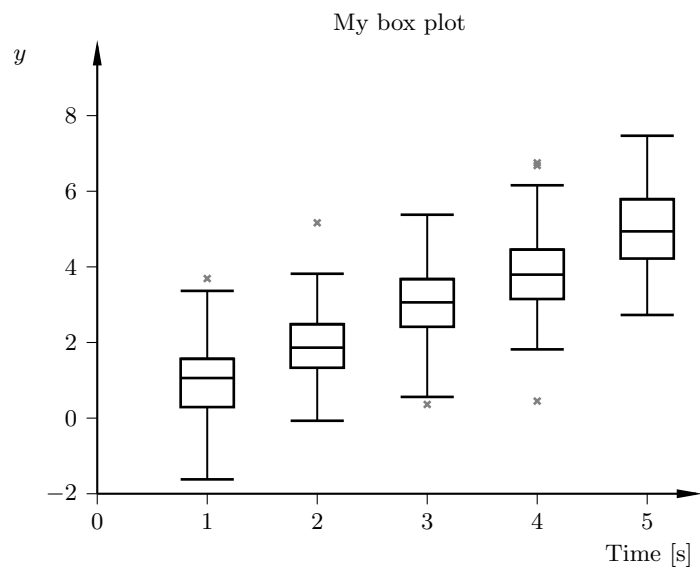
Figure 3: The box plot generated with the code above.