SKILLPILLS

Skill Pill: Julia

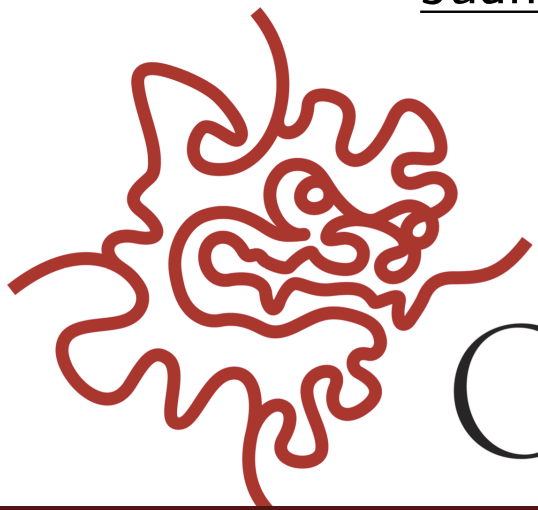
Lecture 2: Data Processing and Plotting

Juan Polo, Friederike, Gaston

juan.polo@oist.jp

material taken/based on Ankur Dhar & James Schloss

February 24th, 2021



OIST

Installing the plotting packages

Plots and Pyplot

```
] add Plots
] add PyPlot
using Plots
import PyPlot
```

Creating Arrays

Arrays in Julia are defined using square brackets [ ]
By default arrays are row vectors, but can be transposed to column vectors

Creating Arrays

Arrays in Julia are defined using square brackets `[ ]`
By default arrays are row vectors, but can be transposed to column vectors
Sequences of numbers can be generated using the `:`
Ranges can be defined as `start:step:end`
To create a vector from a range use the function `collect()`

Creating Arrays

Arrays in Julia are defined using square brackets `[ ]`
By default arrays are row vectors, but can be transposed to column vectors
Sequences of numbers can be generated using the `:`
Ranges can be defined as `start:step:end`
To create a vector from a range use the function `collect()`

```
x = [1 2 3 4]          # 1x4 Array{Int64,2}
y = collect(1:4)       # 4-element Array{Int64,1}
z = [1, 2, 3, 4]       # 4-element Array{Int64,1}
m = [1 2; 3 4]         # 2x2 Array{Int64,2}
w=x'                   # 4x1 {Int64,Array{Int64,2}}
array = Int64[]        # 0-element Array{Int64,1}
```

Creating Arrays

Arrays in Julia are defined using square brackets `[ ]`
By default arrays are row vectors, but can be transposed to column vectors
Sequences of numbers can be generated using the `:`
Ranges can be defined as `start:step:end`
To create a vector from a range use the function `collect()`

```
x = [1 2 3 4]          # 1x4 Array{Int64,2}
y = collect(1:4)       # 4-element Array{Int64,1}
z = [1, 2, 3, 4]       # 4-element Array{Int64,1}
m = [1 2; 3 4]         # 2x2 Array{Int64,2}
w=x'                   # 4x1 {Int64,Array{Int64,2}}
array = Int64[]        # 0-element Array{Int64,1}
```

Please try to create a vector from 0 to 0.9 in steps of 0.1

Creating Arrays

Arrays in Julia are defined using square brackets `[ ]`
By default arrays are row vectors, but can be transposed to column vectors
Sequences of numbers can be generated using the `:`
Ranges can be defined as `start:step:end`
To create a vector from a range use the function `collect()`

```
x = [1 2 3 4]          # 1x4 Array{Int64,2}
y = collect(1:4)       # 4-element Array{Int64,1}
z = [1, 2, 3, 4]       # 4-element Array{Int64,1}
m = [1 2; 3 4]         # 2x2 Array{Int64,2}
w=x'                   # 4x1 {Int64,Array{Int64,2}}
array = Int64[]        # 0-element Array{Int64,1}
```

Please try to create a vector from 0 to 0.9 in steps of 0.1

?range This allows you to create a range without thinking too much. You can combine stop, step and length collect(range(0,stop=10,length=10))

Array Generation Functions

zeros(S)	Makes an array of size S filled with zeros
ones(S)	Makes an array of size S filled with ones
repeat(A,c,r)	Repeats array A column-wise c times and row-wise r times
rand(S)	Generates array of size S with random numbers between 0 and 1
Type[]	Creates empty array of type Type

Array Operations

Arrays are indexed by square brackets after the array `A[1,2]`.

Array Operations

Arrays are indexed by square brackets after the array `A[1,2]`.

```
data = rand(50,50)
data[1,:]
data[:,1]
inner = x*y
outer = y*x
square = x .* x
```

To execute scalar operations on an array, **you can use a . to the operator**. This is also applicable to functions as well.

Array Operations

Arrays are indexed by square brackets after the array `A[1,2]`.

```
data = rand(50,50)
data[1,:]
data[:,1]
inner = x*y
outer = y*x
square = x .* x
```

To execute scalar operations on an array, **you can use a . to the operator**. This is also applicable to functions as well.

Multiply all elements of "x" by a constant "2" (careful with spaces)

Array Operations

Arrays are indexed by square brackets after the array `A[1,2]`.

```
data = rand(50,50)
data[1,:]
data[:,1]
inner = x*y
outer = y*x
square = x .* x
```

To execute scalar operations on an array, **you can use a . to the operator**. This is also applicable to functions as well.

Multiply all elements of "x" by a constant "2" (careful with spaces)

```
2 .* x
```

Broadcasting

Element-by-element binary operations on arrays of different sizes are possible. Dotted operators, `.+` or `.*`, are equivalent to broadcast calls

```
data = collect(0:.1:1)
round.(data)
f(x) = x+2
f.(data)
```

Broadcasting

Element-by-element binary operations on arrays of different sizes are possible. Dotted operators, `.+` or `.*`, are equivalent to broadcast calls

```
data = collect(0:.1:1)
round.(data)
f(x) = x+2
f.(data)
```

Create a vector "v" of dim = 2 (e.g. elements (1, 2)) and add it to the matrix "m" of dim = 2x2

Broadcasting

Element-by-element binary operations on arrays of different sizes are possible. Dotted operators, `.+` or `.*`, are equivalent to broadcast calls

```
data = collect(0:.1:1)
round.(data)
f(x) = x+2
f.(data)
```

Create a vector "v" of dim = 2 (e.g. elements (1, 2)) and add it to the matrix "m" of dim = 2x2

```
v = [1, 2]
m = [1 2; 3 4]
v .+ m
```

Broadcasting

Element-by-element binary operations on arrays of different sizes are possible. Dotted operators, `.+` or `.*`, are equivalent to broadcast calls

```
data = collect(0:.1:1)
round.(data)
f(x) = x+2
f.(data)
```

Create a vector "v" of dim = 2 (e.g. elements (1, 2)) and add it to the matrix "m" of dim = 2x2

```
v = [1, 2]
m = [1 2; 3 4]
v .+ m
```

Extra cool things

```
data[data .< 0.5]
```

Data Handling

File Structure

To **p**rint you current **w**orking **d**irectory pwd()

```
pwd()
# cd("C:\\Users\\M\\Documents\\JuliaStuff")
readdir()
```

Change you current directory `cd("String")`
List the files within using `readdir()`

Delimited text

The simplest data files are delimited text files or CSV files
Requires to load a library DelimitedFiles

```
julia> using DelimitedFiles
julia> data = rand(50,50)
julia> writedlm("Random.txt",data)
julia> randData = readdlm("Random.txt")
```

Similarly, any 1D or 2D can be written to a file, with the actual delimiter being based on the file extension used (txt for space and csv for comma).

Delimited text

The simplest data files are delimited text files or CSV files
Requires to load a library DelimitedFiles

```
julia> using DelimitedFiles
julia> data = rand(50,50)
julia> writedlm("Random.txt",data)
julia> randData = readdlm("Random.txt")
```

Similarly, any 1D or 2D can be written to a file, with the actual delimiter being based on the file extension used (txt for space and csv for comma).

Hierarchical Data Format (HDF5) can be an interesting format to save arrays and data.

CSV files

CSV files are a bit more complex than standard delimited files, including headers or labels.
A specific library can be loaded CSV.
The first row will be taken as the header row (this can be explicitly defined)

```
using CSV, DataFrames
data =
    DataFrame(CSV.File("simplemaps-worldcities-basic.csv"))
names(data)
populations = data[:,:pop]
populations = data.pop
data[5677,:]
```

Small trick, you can write "`data.`" and press "TAB" twice to see the available columns

```
data[data.city .== "Barcelona",:]
findall(x->x=="Barcelona",data.city)
```

Exercises

Exercise 1

Creates a file `squares.txt` consisting of the first 5 square numbers

Exercise 2

Write a script which creates a new file called `large_cities.txt`. The file should contain one line for each of the cities which have a population larger than 10,000,000., formatted as follows:
Buenos Aires, Argentina: population 11862073
Sao Paulo, Brazil: population 14433147.5
...

Exercises

Exercise 1

Creates a file `squares.txt` consisting of the first 5 square numbers

Exercise 2

Write a script which creates a new file called `large_cities.txt`. The file should contain one line for each of the cities which have a population larger than 10,000,000., formatted as follows:
Buenos Aires, Argentina: population 11862073
Sao Paulo, Brazil: population 14433147.5
...

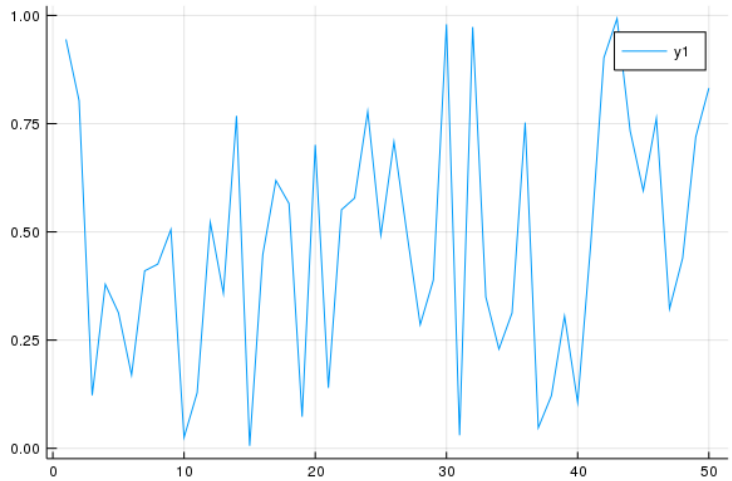
Fast way to look at data using Dataframes `data[data.pop .> 10^7,:]`

Plots

Plots in a Nutshell

Let's add and load the general Plots package

```
# inside pkg>
add Plots
# inside REPL
using Plots
# plot(Plots.fakedata(50))
```



This will let us call the general Plot commands, in this case `plot` plots 1D data as a line plot.
More information can be found at `https://docs.juliaplots.org/latest/`

Plotting Commands

scatter(X,Y)	Scatter plot data with XY coordinates
bar(x,y)	Bar plot following similar rules to plot
histogram(x,bins=n)	Plots histogram of 1D data in n bins.
plot(θ,r,proj=:polar)	Polar plot of data following r and θ
heatmap(x,y,z)	Plots heatmap following XY axes with intensity array z
fakedata(L,S)	Generates random S numbers of series data of length L
savefig(filename)	Saves a generated plot as an image file

Plotting 3D Data

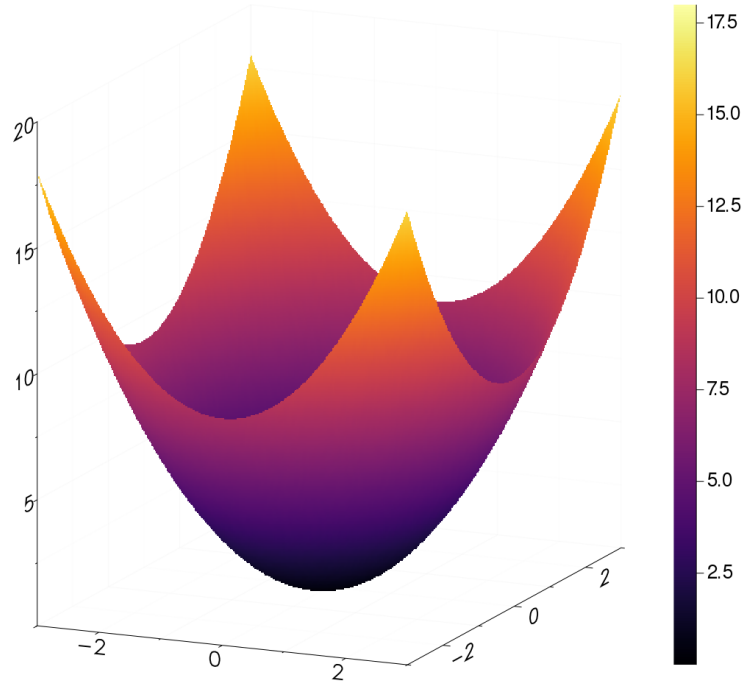
There are a couple of additional options for plotting 3D data:

surface(x,y,z) Draws surface in 3D space

contour(x,y,z) Draws contours on 2D plane

heatmap(x,y,z) Draws a heatmap on 2D plane

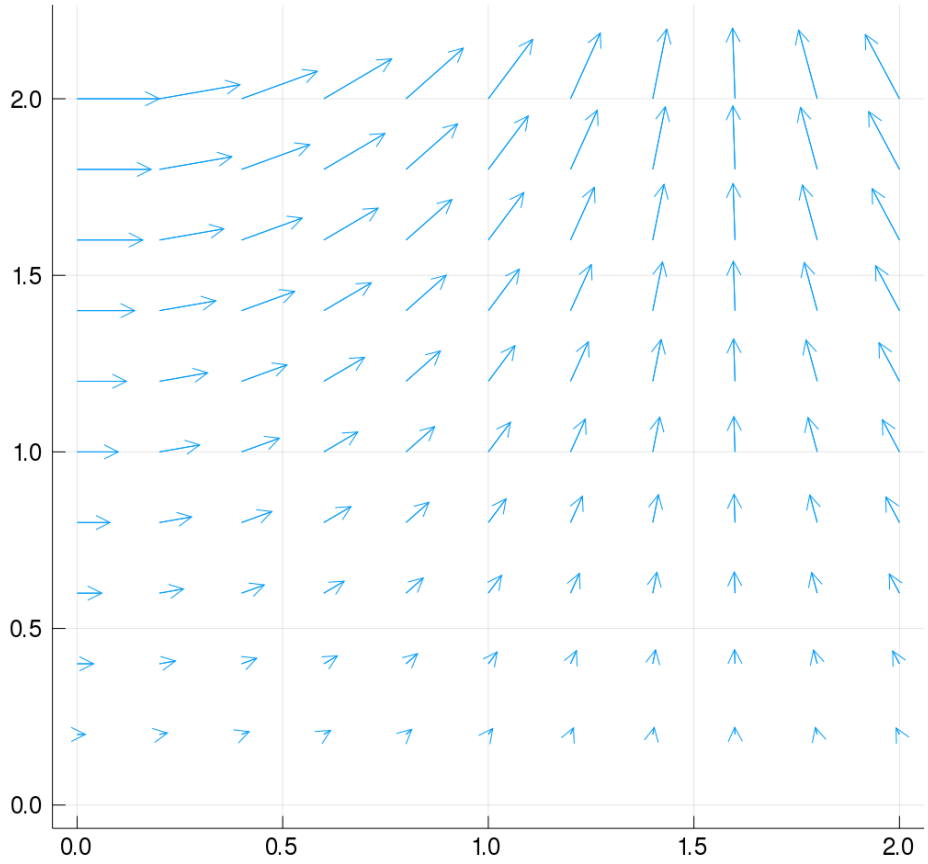
The plotting commands `plot`,`scatter`,`bar`, and `heatmap` also can accept 3D data.



Plotting Vector Data

For vector data the current option is quiver:

```
help?> quiver
search: quiver quiver!

quiver(x,y,quiver=(u,v))
quiver!(x,y,quiver=(u,v))

Make a quiver (vector field)
    plot. The ith vector
    extends from (x[i],y[i])
    to (x[i] + u[i], y[i] +
    v[i]).
```



Plotting Backends

These commands are agnostic to the plotting backend, meaning they will work with a number of plotting engines in similar fashion. Each backend has pros and cons, but most commonly used are GR and PyPlot.

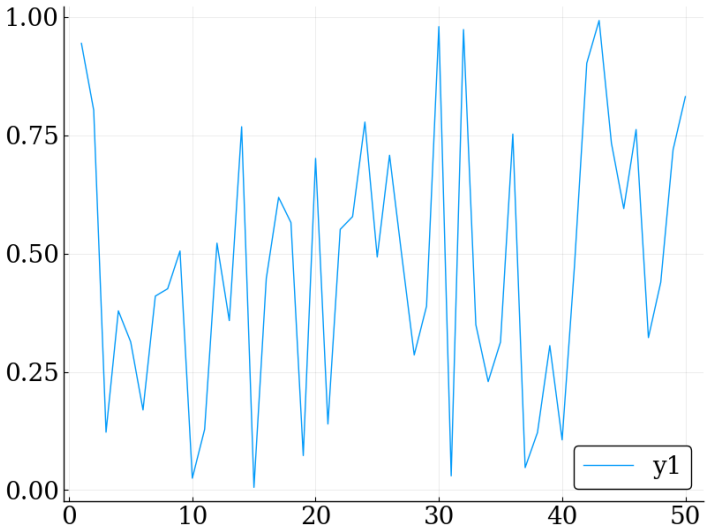


Figure: PyPlot
using PyPlot; PyPlot.plot(rand(10))

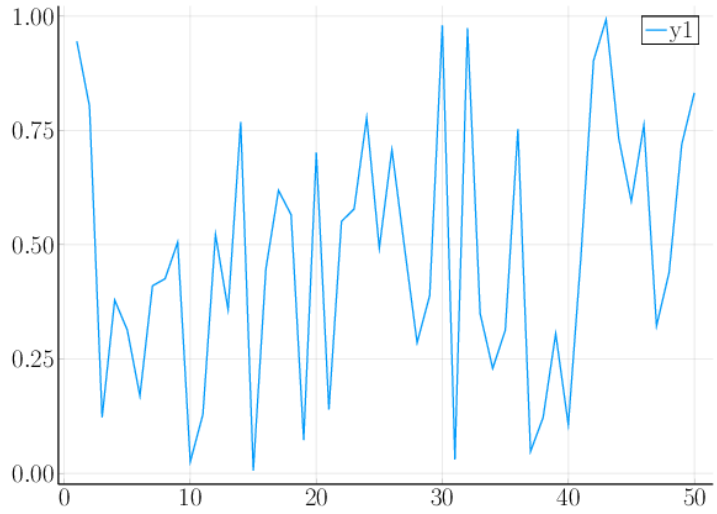
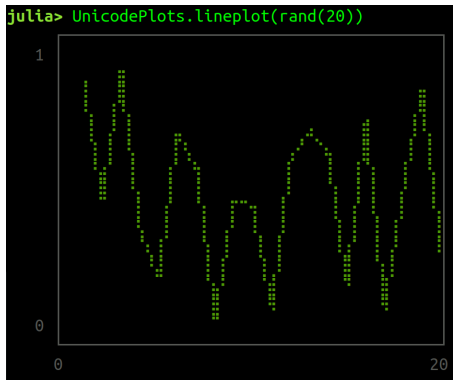


Figure: PGFPlots



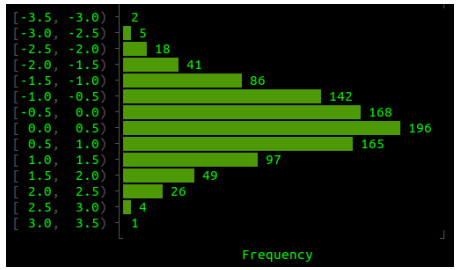


Figure: UnicodePlots
using UnicodePlots; UnicodePlots.lineplot(rand(10))
UnicodePlots.histogram(randn(1000),nbins=15,closed=:left)

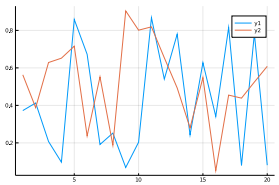
Examples of plots

You can load one or multiple plot libraries but they might have conflicts. Using "Plots.plot" or "PyPlot.plot" will force a particular library.
The default backend can be changed by "backend(:gr)" or "backend(:pyplot)"

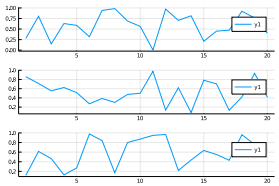
Examples of plots

You can load one or multiple plot libraries but they might have conflicts. Using "Plots.plot" or "PyPlot.plot" will force a particular library.
The default backend can be changed by "backend(:gr)" or "backend(:pyplot)"

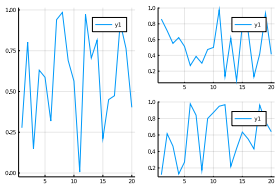
```
using Plots; import PyPlot; plt = PyPlot;
# Import avoids conflicts, however PyPlot.XXX or plt.XXX is
    need to use that library

plot(rand(20))     # generates a plot
plot(rand(20))     # generates a new plot
plot!(rand(20))    # add line to previous plot
```



```
p1 = plot(rand(20)); # the semicolon will prevent plotting
p2 = plot(rand(20));
p3 = plot(rand(20));
plot(p1,p2,p3) # Automatically generates a layout
```

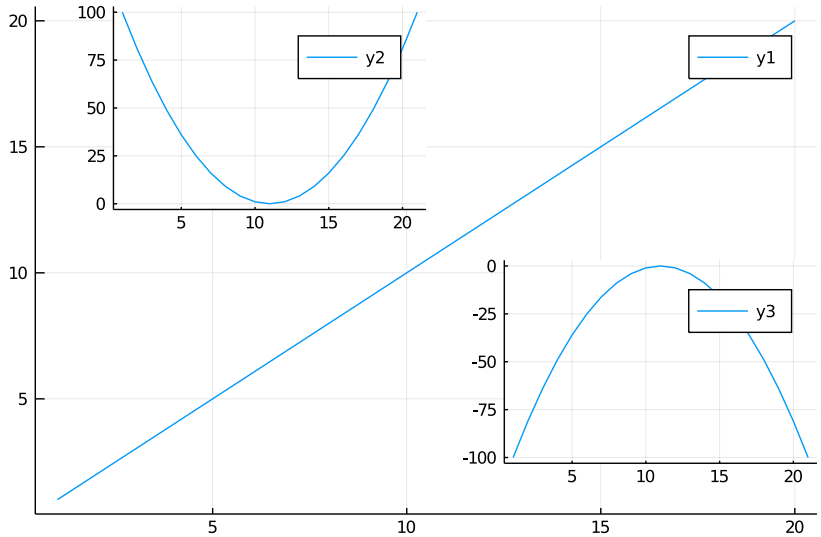


```
# Manually generating a layout
plot(p1,p2,p3, layout = @layout grid(3,1))
plot(p1,p2,p3, layout = @layout [a [b; c]])
```



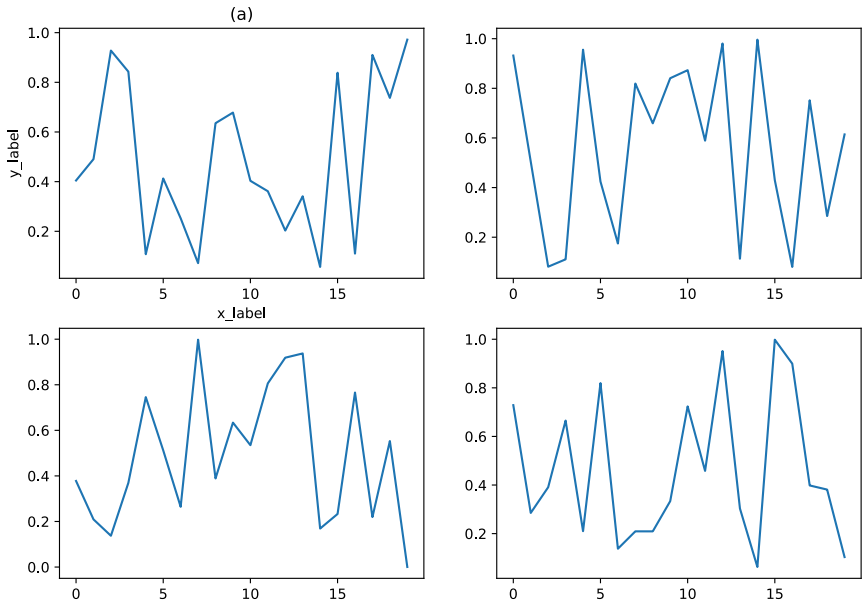
Examples of plots

```
using Plots; import PyPlot; plt = PyPlot;
# Import avoids conflicts, however PyPlot.XXX or plt.XXX is
    need to use that library

# Plot with two insets
plot(1:20)
plot!((-10:10).^2, inset = (1, bbox(0.1,0.0,0.4,0.4)),
    subplot = 2)
plot!(-(-10:10).^2, inset = (1, bbox(0.6,0.5,0.4,0.4)),
    subplot = 3)
```



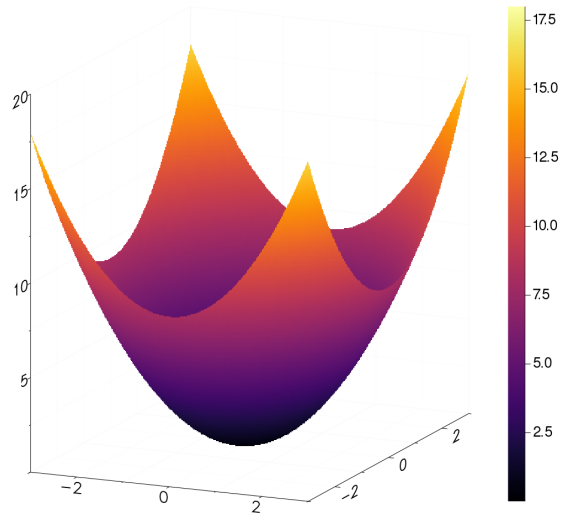
Examples of plots with PyPlot

```
using Plots; import PyPlot; plt = PyPlot;
# we have to use plt.XXX for the main commands

fig, axs = plt.subplots(ncols=2,nrows=2);


axs[1,1].plot(rand(20));
axs[1,2].plot(rand(20));
axs[2,1].plot(rand(20));
axs[2,2].plot(rand(20));

axs[1,1].set_title("(a)")
axs[1,1].set_xlabel("x_label")
axs[1,1].set_ylabel("y_label")


plt.clf(); # this will clear the figure
```



Plotting 3D examples

```
using Plots
x = y = collect(-1:0.01:1)
#surface(x,y,(x,y)->x^2+y^2)
#heatmap(x,y,(x,y)->x^2+y^2)
f(x,y) = x^2 + y^2
surface(x,y,f.(x,y'))
contour(x,y,f.(x,y'))
heatmap(x,y,f.(x,y'))
```



Examples

Each of these commands can be expressed in-line with the plotting command or beforehand within a call to the plotting backend.

font(fontname,size)	Defines a Font object with a given size
size=(X,Y)	Sets size of plot to X by Y pixels
xlabel=string	Sets X-Y labels to string, also ylabel
title=string	Sets title to string, also colorbar_title for heatmap.
xtickfont=font	Sets the font of x tick marks, also ytickfont,titlefont,guidefont
left_margin=length	Sets margin for left side of plot, also top_margin, bottom_margin, and right_margin
xscale=:log10	Sets x scale to log10, also yscale

Exercises

Exercise 3

Read data.txt given in the Public Folder and plot the results. What do you see?

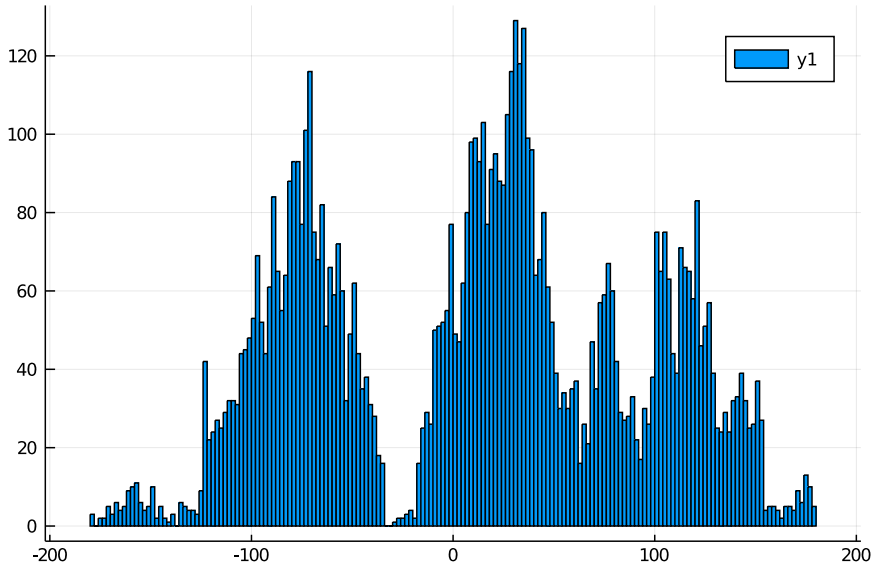
Exercise 4

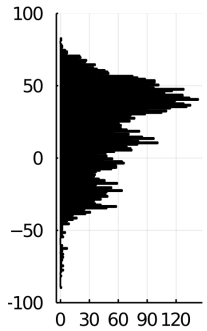
Plot a histogram of the longitudes and latitudes of the world's cities.

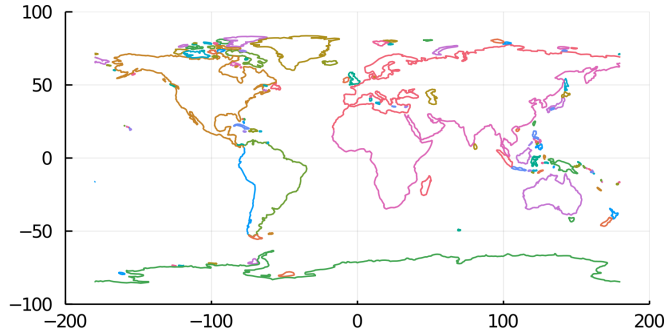
```
using Plots, DataFrames, CSV
data = DataFrame(CSV.File("simplemaps-worldcities-basic.csv"))
```

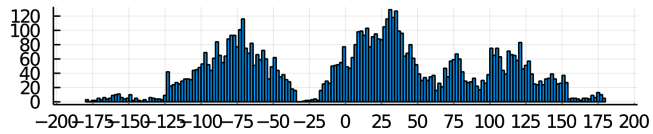
Exercise 4 solution

```
using Plots, Images, ImageMagick, DataFrames, CSV

data =
    DataFrame(CSV.File("simplemaps-worldcities-basic.csv"))

histogram(data.lng,bins=200)
histogram(data.lat)
```









My image

```
using Plots, Images, ImageMagick, DataFrames, CSV,Shapefile

data = DataFrame(CSV.File("simplemaps-worldcities-basic.csv"))

shp =
    Shapefile.shapes(Shapefile.Table("ne_110m_coastline.shp"));

p3 = histogram(data.lng,bins=200,xticks = (-
    200:25:200),label=false);
p2 = plot(shp,xlim=(-200,200),ylim=(-100,100));
p2_size = p2.attr.explicit[:size];

p1 = histogram(data.lat,bins=200,ylim = (-100,100),
  orientation=:horizontal,
  aspect_ratio=p2_size[1]/p2_size[2],label=false);

plot(p1,p2,p3,p3,
  layout=@layout [[a{0.2w} b{0.8h}]; [c d]])
```

What is next?

Last Session (Gaston) IDEs, Data Structures, Coding Practices, and Algorithms