midterm_notebook

April 9, 2024

This serves as a demonstration of the work we have been able to complete so far, with particular focus on cubic splines and our methods for data analysis

[ ]:
```
## Data tool kit we developed
include("../../datatools.jl")
using CSV, DataFrames, Statistics, LinearAlgebra, Plots, Polynomials
```

Each road that we are sampling is contained within its own directory. If the road has opposing sidewalks, these have been further subdivided into West and East to denote where the data was collected.

Demonstrated below is the core data structure for our analysis, a vector of DataFrames with each element representing a unique sample from a given road. Methods are also in place to combine the vector into a single dataframe, from which they will be delimited using an additional "Sample" column

---

Function doc strings ⇓

[ ]:
```
## Function doc string
display("text/markdown",Base.doc(get_folder_dataframes))
```

`get_folder_dataframes(foldername::String)`

takes in the name of a folder or the path to a subfolder in /data/ . returns a vector of all the dataframes in that folder

`sweetwater_dataframes = get_folder_dataframes("Sweetwater")`

[ ]:
```
sweetwater_dataframes = get_folder_dataframes("Sweetwater")
```

```
2-element Vector{Any}:
 790×11 DataFrame
 Row  time                 seconds_elapsed  bearingAccuracy  speedAccuracy  v
      Int64                Float64          Float64          Float64        F

   1  1712266854188000000            0.755             45.0           1.5
   2  1712266855367640000          1.93464          49.5444       0.778974
   3  1712266856366407200          2.93341           69.841        1.44903
   4  1712266857366600000           3.9336          73.7154        1.35204
```

5	1712266858367190800	4.93419	11.7684	0.700928
6	1712266859366409700	5.93341	52.3302	1.18339
7	1712266860366214400	6.93321	45.0	1.5
8	1712266860698761000	7.26576	45.0	1.5
784	1712267136367092200	282.934	45.0	0.229789
785	1712267136732062500	283.299	45.0	0.238457
786	1712267137299000000	283.866	45.0	0.267136
787	1712267137366789600	283.934	45.0	0.23065
788	1712267137853849300	284.421	45.0	0.224196
789	1712267138366343000	284.933	45.0	0.232099
790	1712267138530313500	285.097	45.0	0.190602

7 columns and 775 rows omitted

793×11 DataFrame

Row	time	seconds_elapsed	bearingAccuracy	speedAccuracy	v
	Int64	Float64	Float64	Float64	F
1	1712267185717000000	0.739	45.0	1.5	
2	1712267187368109600	2.39011	45.0	0.762168	
3	1712267188367858000	3.38986	96.3981	1.37928	
4	1712267189367884500	4.38988	10.0215	1.09604	
5	1712267190367785200	5.38979	14.5783	0.432782	
6	1712267191367374800	6.38937	46.9725	1.09604	
7	1712267192368158200	7.39016	38.3759	0.849058	
8	1712267192997000000	8.019	45.0	1.5	
787	1712267466930966800	281.953	45.0	0.161448	
788	1712267467368184800	282.39	45.0	0.192319	
789	1712267467511210200	282.533	45.0	0.193773	
790	1712267468070694000	283.093	45.0	0.202665	
791	1712267468118965200	283.141	45.0	0.202665	
792	1712267468367581200	283.39	45.0	0.21216	
793	1712267468574563600	283.597	45.0	0.212766	

7 columns and 778 rows omitted

Our intention is to gather a bunch of samples for each road, and then average the samples together. Our method of data collection uses a sensor that records ‘x’ number of points every second. Since multiple individuals are collecting data on different days and at different times, and are presumably traveling at different speeds, it is unlikely that each sample will contain points from the exact same locations. This is further exacerbated by the sensor recording values down to 15 decimal places, making it unlikely to get a recording from the same position in more than one sample. To account for this, we have developed a function which evaluates the dataframes at a column of interest (which can be specified), and rounds the values to a specified number of digits. It then finds common points of intersection between samples, averages them, and returns the resulting dataframe, now pruned to only contain the necessary columns (latitude, longitude, and altitude).

Function doc strings ⇓

```
[ ]: display("text/markdown",Base.doc(get_filtered_points))
```

`get_filtered_points(dfs::Vector{Any}, column_name::String="latitude"; round_to::Int=5, only_un`

Takes in vector of dataframes generated by get*folder*dataframes. User specifies a column_name by which to compare the dataframes. Values are rounded to 5 by default, but can be changed. The dataframes are trimmed based on these matching rounded values, and only the columns latitude, longitude, and altitude are returned. These are all that are needed for displaying the points

```
filtered_points = get_filtered_points(folder_dataframes, "latitude"; round_to=3)
```

```
[ ]: display("text/markdown",Base.doc(combine_df_vectors))
```

`combine_df_vectors(dfs::Vector{Any}; already_filtered::Bool=true, round_to::Int=5)`

This function takes in a vector of dataframes from the same road (similar samples). It will compare the vectors and average them together. Unique sample latitudes will instead be appended into the new dataframe. The function assumes that you are passing in the returned value of get*filtered*points, but allows for you to set already_filtered=false if the data is unfiltered

```
sweetwater_dfs = get_folder_dataframes("Sweetwater");

filtered_sw_points = get_filtered_points(sweetwater_dfs);

sw_points = combine_df_vectors(filtered_sw_points)

## alternatively
sw_points = combine_df_vectors(sweetwater_dfs; already_filtered=false)
```

```
[ ]: sweetwater_filtered_points = get_filtered_points(sweetwater_dataframes)
```

2-element Vector{Any}:

296×3 DataFrame

Row	latitude	longitude	altitude
	Float64	Float64	Float64
1	29.6418	-82.3482	-3.4
2	29.6418	-82.3482	-1.2
3	29.6418	-82.3482	-2.2
4	29.6418	-82.3482	-2.2
5	29.6418	-82.3482	-2.2
6	29.6418	-82.3482	-2.2
7	29.6419	-82.3482	-2.2
8	29.6419	-82.3482	-2.2
290	29.6447	-82.3487	8.0551
291	29.6447	-82.3487	8.0551
292	29.6447	-82.3487	8.08144
293	29.6447	-82.3487	7.98812

294	29.6447	-82.3487	7.85234
295	29.6447	-82.3487	7.6329
296	29.6447	-82.3487	7.59701

281 rows omitted

296×3 DataFrame

Row	**latitude**	**longitude**	**altitude**
	Float64	Float64	Float64
1	29.6418	-82.3482	-2.2
2	29.6418	-82.3482	-2.2
3	29.6418	-82.3482	-2.2
4	29.6418	-82.3482	-2.2
5	29.6418	-82.3482	-3.4
6	29.6418	-82.3482	-3.4
7	29.6419	-82.3482	-3.4
8	29.6419	-82.3482	-3.4
290	29.6447	-82.3487	6.1
291	29.6447	-82.3487	6.1
292	29.6447	-82.3487	6.1
293	29.6447	-82.3487	6.2
294	29.6447	-82.3487	6.2
295	29.6447	-82.3487	6.2
296	29.6447	-82.3487	6.2

281 rows omitted

[ ]:
```
# Averaged sample

sweetwater_averaged_df = combine_df_vectors(sweetwater_filtered_points)
```

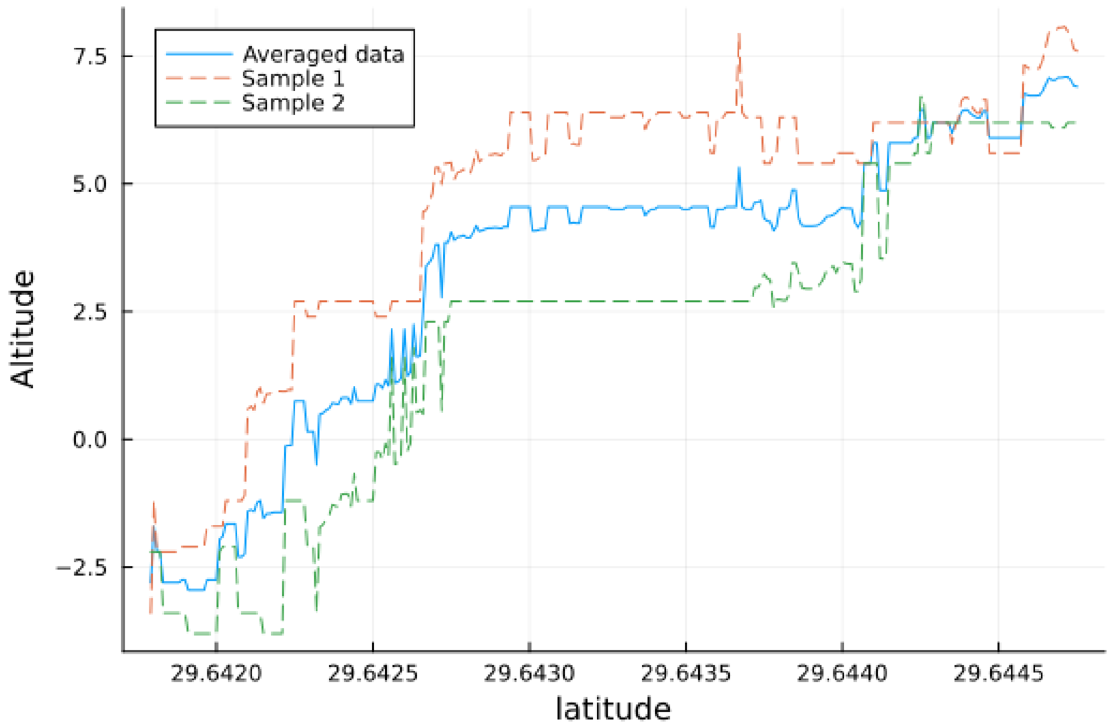
	latitude	longitude	altitude
	Float64	Float64	Float64
1	29.6418	-82.3482	-2.8
2	29.6418	-82.3482	-1.7
3	29.6418	-82.3482	-2.2
4	29.6418	-82.3482	-2.2
5	29.6418	-82.3482	-2.8
6	29.6418	-82.3482	-2.8
7	29.6419	-82.3482	-2.8
8	29.6419	-82.3482	-2.8
9	29.6419	-82.3482	-2.8
10	29.6419	-82.3482	-2.8
11	29.6419	-82.3482	-2.75
12	29.6419	-82.3482	-2.75
13	29.6419	-82.3483	-2.95
14	29.6419	-82.3483	-2.95
15	29.6419	-82.3483	-2.95
16	29.6419	-82.3483	-2.95
17	29.642	-82.3483	-2.95
18	29.642	-82.3483	-2.95
19	29.642	-82.3483	-2.75
20	29.642	-82.3483	-2.75
21	29.642	-82.3483	-2.75
22	29.642	-82.3483	-2.75
23	29.642	-82.3483	-1.95
24	29.642	-82.3483	-1.9
…	…	…	…

[ ]:
```
x  = sweetwater_filtered_points[1].latitude;
y  = sweetwater_filtered_points[1].altitude;

x  = sweetwater_filtered_points[2].latitude;
y  = sweetwater_filtered_points[2].altitude;

x̄ = sweetwater_averaged_df.latitude;
ȳ = sweetwater_averaged_df.altitude;


plt = plot(x̄, ȳ, label="Averaged data", ylabel="Altitude", xlabel="latitude")
plot!(plt, x , y , label="Sample 1", ls=:dash)
plot!(plt, x , y , label="Sample 2", ls=:dash)
```



Demonstration of our current work on cubic splines:

[ ]:
```
function spinterp(t,y)
     n = length(t)-1
     h = [ t[k+1]-t[k] for k in 1:n ]

     # Preliminary definitions.
     Z = zeros(n,n);
     In = I(n);  E = In[1:n-1,:];
     J = diagm(0=>ones(n),1=>-ones(n-1))
     H = diagm(0=>h)

     # Left endpoint interpolation:
     AL = [ In Z Z Z ]
     vL = y[1:n]

     # Right endpoint interpolation:
     AR = [ In H H^2 H^3 ];
     vR = y[2:n+1]

     # Continuity of first derivative:
     A1 = E*[ Z J 2*H 3*H^2 ]
```

```
    v1 = zeros(n-1)

    # Continuity of second derivative:
    A2 = E*[ Z Z J 3*H ]
    v2 = zeros(n-1)

    # Not-a-knot conditions:
    nakL = [ zeros(1,3*n) [1 -1 zeros(1,n-2)] ]
    nakR = [ zeros(1,3*n) [zeros(1,n-2) 1 -1] ]

    # Assemble and solve the full system.
    A = [ AL; AR; A1; A2; nakL; nakR ]
    v = [ vL; vR; v1; v2; 0; 0 ]
    z = A\v

    # Break the coefficients into separate vectors.
    rows = 1:n
    a = z[rows]
    b = z[n.+rows];  c = z[2*n.+rows];  d = z[3*n.+rows]
    S = [ Polynomial([a[k],b[k],c[k],d[k]]) for k in 1:n ]

    # This function evaluates the spline when called with a value
    # for x.
    return function (x)
        if x < t[1] || x > t[n+1]    # outside the interval
            return NaN
        elseif x==t[1]
            return y[1]
        else
            k = findlast(x .> t)    # last node to the left of x
            return S[k](x-t[k])
        end
    end
end
```

spinterp (generic function with 1 method)

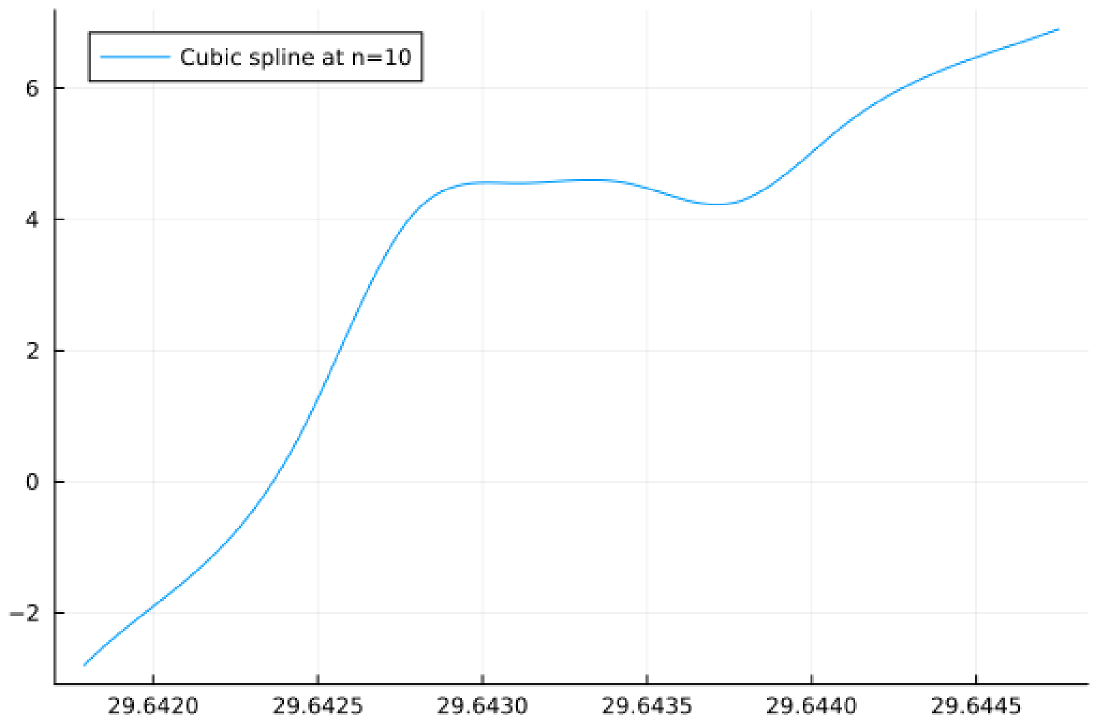
[ ]:
```
function plot_cubic_spline(plt, x, y, n=10; la=0.6, fa=0.0)
    # x_sorted = sort(x, rev=true);
    xs, ys = get_spaced_nodes(x, y, n);
    cspline_f = spinterp(xs, ys)
    plot!(plt, x, cspline_f.(x), fillrange=y, fillalpha = fa, label="n=$n",ls=:
 ↪dash, alpha=la)
end
```

plot_cubic_spline (generic function with 2 methods)

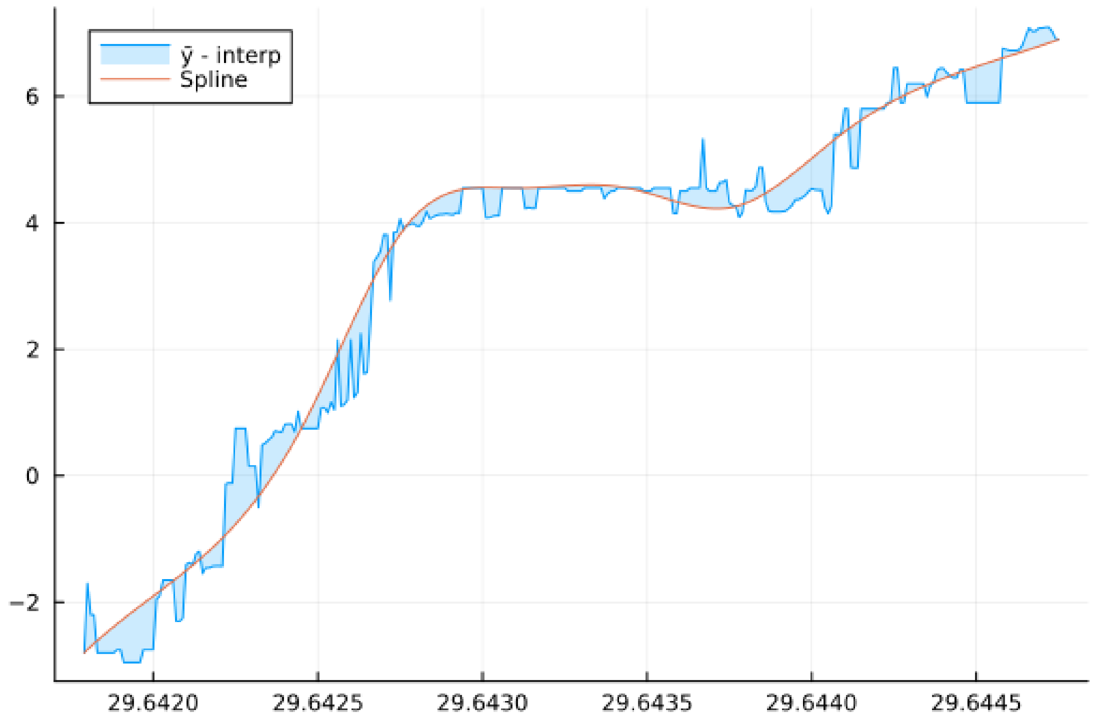
[ ]:
```
xn, yn = get_spaced_nodes(x̄, ȳ, 10)

cspline_f = spinterp(xn, yn)

plot(x̄, cspline_f.(x̄), label="Cubic spline at n=10")
```



[ ]:
```
plt = plot(x̄, ȳ, fillrange=cspline_f.(x̄), fillalpha=0.2, label="ȳ - interp")
plot!(x̄, cspline_f.(x̄), label="Spline")
```



[ ]:

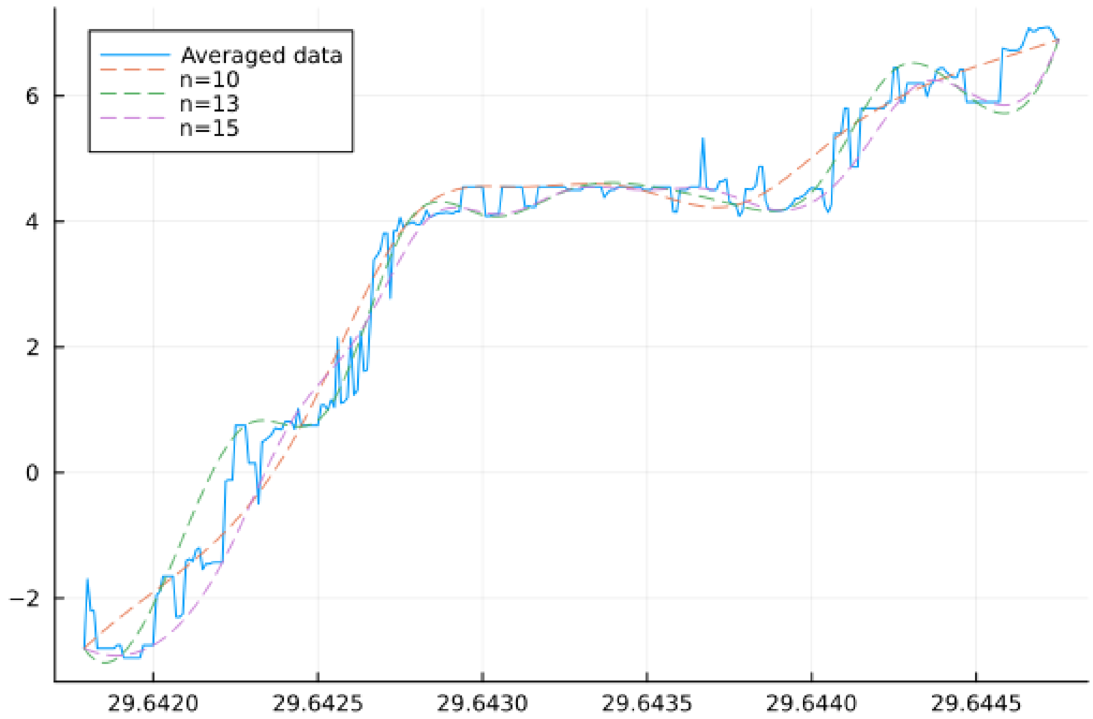
```

```

[ ]:

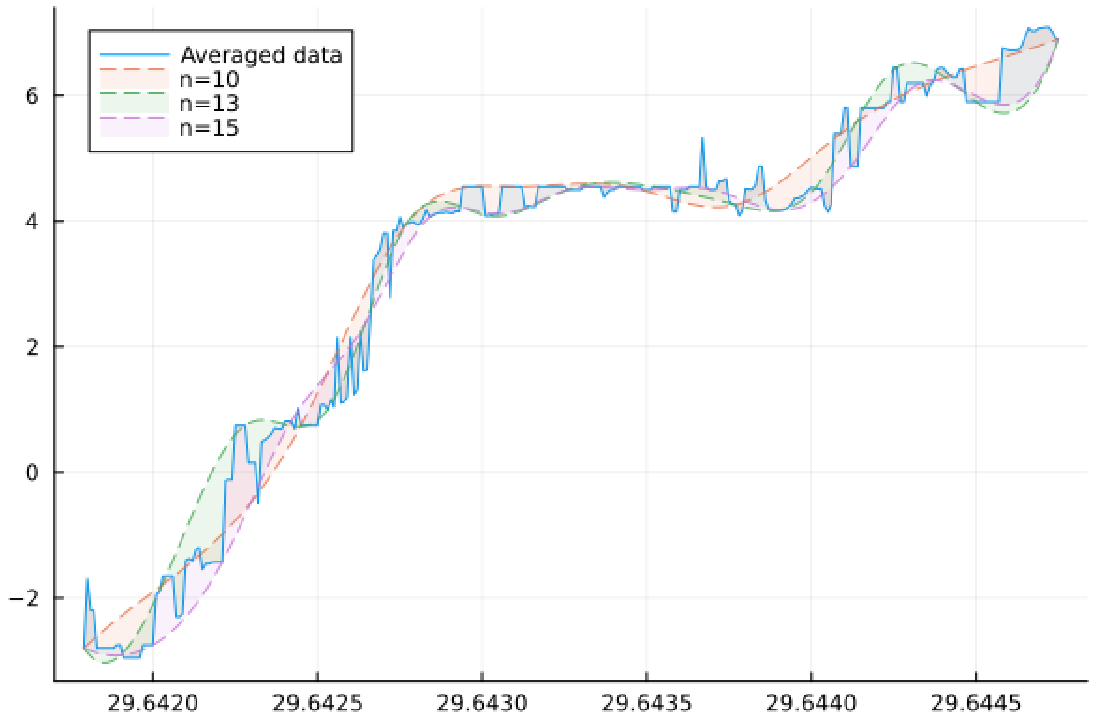
```
plt = plot(x̄, ȳ, label="Averaged data");

for n=[10,13,15]
    plot_cubic_spline(plt, x̄, ȳ, n; la=0.8)
end
plt
```



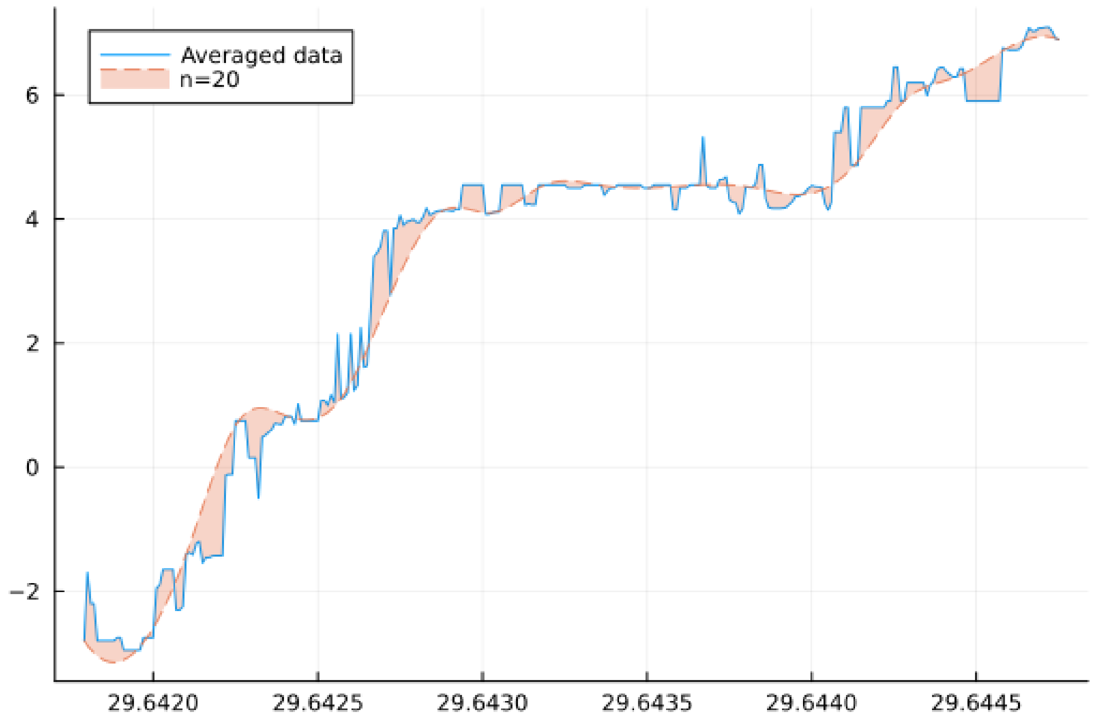
[ ]:
```
plt = plot(x̄, ȳ, label="Averaged data");

for n=[10,13,15]
    plot_cubic_spline(plt, x̄, ȳ, n; la=0.8, fa=0.1)
end
plt
```



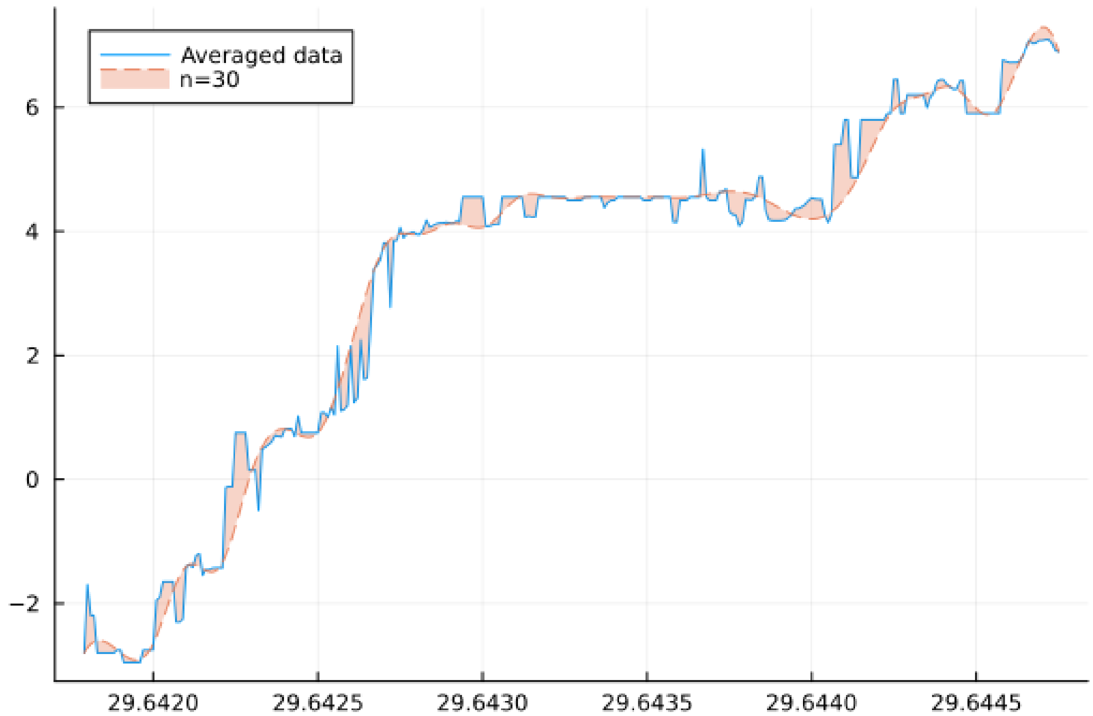
Choosing our n values carefully is critical to avoid overfitting, we increasing this value just a bit shows such

[ ]:
```
plt = plot(x̄, ȳ, label="Averaged data");
plot_cubic_spline(plt, x̄, ȳ, 20; la=0.8, fa=0.3)
```



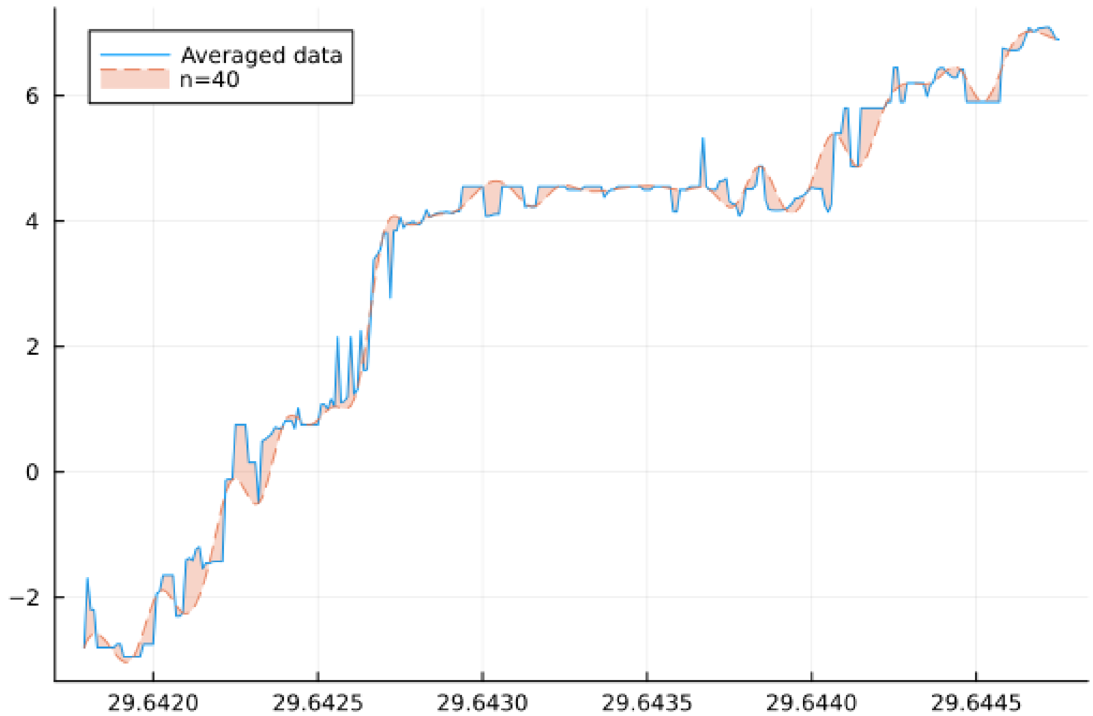
Taking this further

[ ]:
```
plt = plot(x̄, ȳ, label="Averaged data");
plot_cubic_spline(plt, x̄, ȳ, 30; la=0.8, fa=0.3)
```



Oncemore

```
[ ]: plt = plot(x̄, ȳ, label="Averaged data");
     plot_cubic_spline(plt, x̄, ȳ, 40; la=0.8, fa=0.3)
```



We have opted for n values in the range $[10, 15]$. In our testing we have found that these provide adhesion and smoothness to the data without overly matching the original values

We believe that this careful selection of n values and averaging our samples will aid in producing smooth, accurate results that are not overfit. Moreover, our function `get_spaced_nodes` will grab n number of values from the dataset that are equidistant, thus forming a box-spline. We have added in the parameter `fluctuation`, that will shift indices by a random value in the range $\pm$ fluctuation. This excluded the first and last index to ensure that the splines are being fit to the entire breadth of the sample. This may provide additional information on the nature of the data

[ ]:
```
display("text/markdown",Base.doc(get_spaced_nodes))
```

`get_spaced_nodes(x, y, n=10; rev=true, fluctuation::Int=0)`

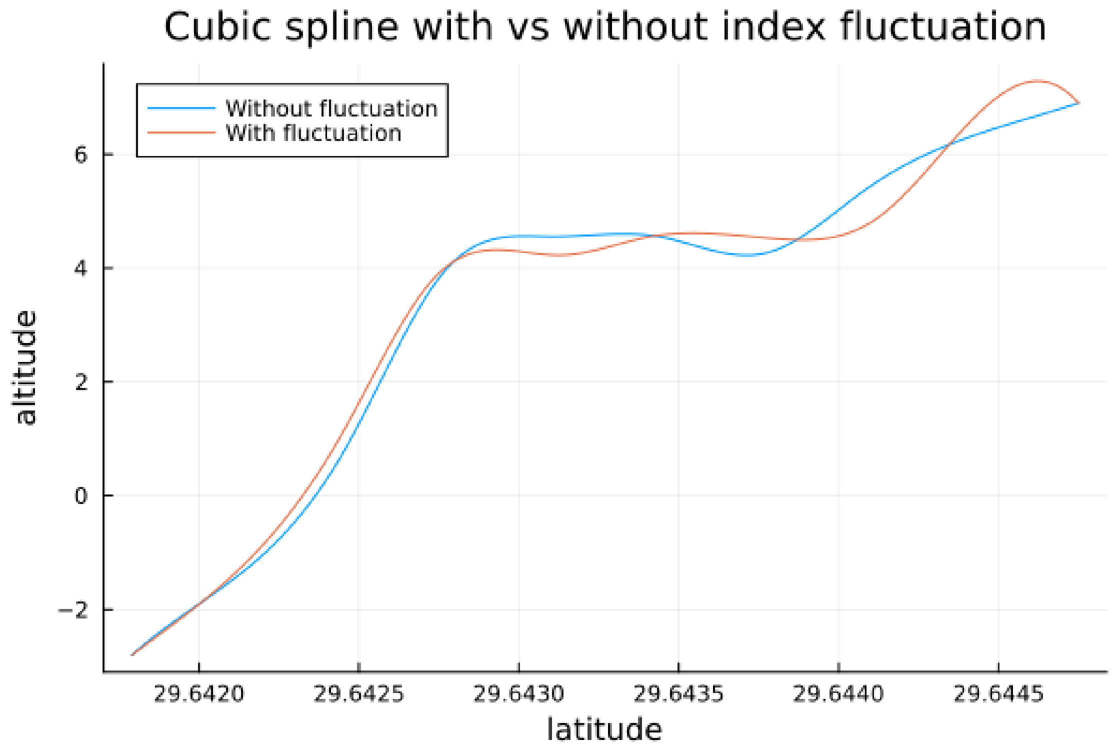
Takes in x and y values. returns 'n' number of spaced out points from the data. By default this will return evenly spaced points, but setting fluctuation=SOME_INT will cause each index to change by $\pm$ a value in the range [-fluctuation , fluctuation]

[ ]:
```
xn2, yn2 = get_spaced_nodes(x̄, ȳ, 10; fluctuation=5);

cspline_f2 = spinterp(xn2, yn2);

plot(x̄, cspline_f.(x̄), label="Without fluctuation", title="Cubic spline with vs␣
  ↪without index fluctuation")
```

```
plot!(x̄, cspline_f2.(x̄), label="With fluctuation", ylabel="altitude",␣
    ↪xlabel="latitude")
```




```
[ ]:
```