This was a very interesting lab that made me think about good, simple and accurate model for measurement. By every new value I was entering on the paper it was more and more clear to me that a good, simple and accurate model for measurement does not exist.

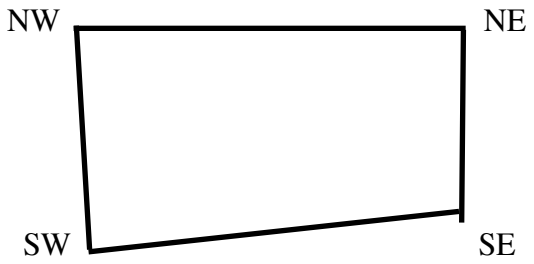
At first glance, it looked to me that shape is rectangular and that it is going to be extra easy to determine exact area of it. On my way to school I started to measure SE - NE distance by "The no-technology-at-all device" just by counting how many of my "white Puma sneakers" can fit in to the SE - NE distance. I got so many strange looks. Few times I tried to explain what I am doing, once done explaining I would forget where I stopped exactly so starting over and getting even more strange looks would be the only solution.

The length of my snicker is 30cm (so whatever is the count I would multiply it by 30cm) and the results I got by measuring distance with "The no-technology-at-all device" is following:

The no-technology-at-all device	
Side	**Length**
SE - NE	45.95 m
NE - NW	62.55 m
NW - SW	47.10 m
SW - SE	62.70 m

This data showed me that we are not talking about rectangle at all. This shape had 4 unequal sides. NE-NW and SW-SE are very similar (15cm difference) but NE-NW and NW-SW were less similar (1.15 m).

I also realized that a shape of object looks like this:



The distance that sticks on the SE side of NE-SE side is 30cm which I subtracted from all SE-NE measurements. In addition to "The no-technology-at-all device" I used three more devices: measuring tape, large measuring wheel and small measuring wheel.

Here are the raw results:

	Wheel Big		Wheel small		Measuring tape		Puma snickers	
Side	**All**	**Average**	**All**	**Average**	**All**	**Average**	**All**	**Average**
SE - NE	44.63 m	**44.61 m**	44.70 m	**44.69 m**	44.53 m	**44.53 m**	45.90 m	**45.80 m**
	44.60 m		44.70 m		44.50 m		45.90 m	
	44.60 m		44.68 m		44.56 m		45.60 m	
NE - NW	61.72 m	**61.70 m**	61.96 m	**61.96 m**	61.60 m	**61.60 m**	62.55 m	**62.45 m**
	61.71 m		61.96 m		61.60 m		62.25 m	
	61.69 m		61.95 m		61.60 m		62.55 m	
NW - SW	45.96 m	**45.98 m**	46.02 m	**46.10 m**	45.93 m	**45.93 m**	46.80 m	**47.10 m**
	45.99 m		46.12 m		45.93 m		47.10 m	
	45.99 m		46.15 m		45.93 m		47.40 m	
SW - SE	61.78 m	**61.77 m**	61.84 m	**61.90 m**	61.72 m	**61.72 m**	62.70 m	**62.80 m**
	61.78 m		61.96 m		61.72 m		63.0 m	
	61.75 m		61.87 m		61.72 m		62.70 m	

I realized that average numbers are consistently smallest when measured by “measuring tape” and the biggest when measuring with my “snickers”. There fore I color coded averages with different yellow color (brighter color smaller averages).

We discuss a couple of methods for measuring the area when all 4 sides are different. My favorite is dividing our object in one rectangle and one triangle and than calculating their areas separately. It turned out this is not very practical because non of the angles are exactly 90 degrees. So I decided to average SE-NE and NW-SW sides as well NE-NW and SW-SE sides and calculate area of rectangle. Here is the cleaned up data:

	Wheel Big	Wheel small	Measuring tape	Puma snickers
Side	**Average**	**Average**	**Average**	**Average**
SE - NE	**45.29 m**	**45.39 m**	**45.23 m**	**46.45 m**
NE - NW	**61.73 m**	**61.93 m**	**61.66 m**	**62.62 m**
NW - SW	**45.29 m**	**45.39 m**	**45.23 m**	**46.45 m**
SW - SE	**61.73 m**	**61.93 m**	**61.66 m**	**62.62 m**

Even after averaging distances: (SE-NE + NW-SW)/2 and (NE-NW + SW-SE)/2 the color coding we used for raw data still applies on cleaned up data.

In order to calculate area we use height * width formula. In our case ((SE-NE)* (NE-NW)).

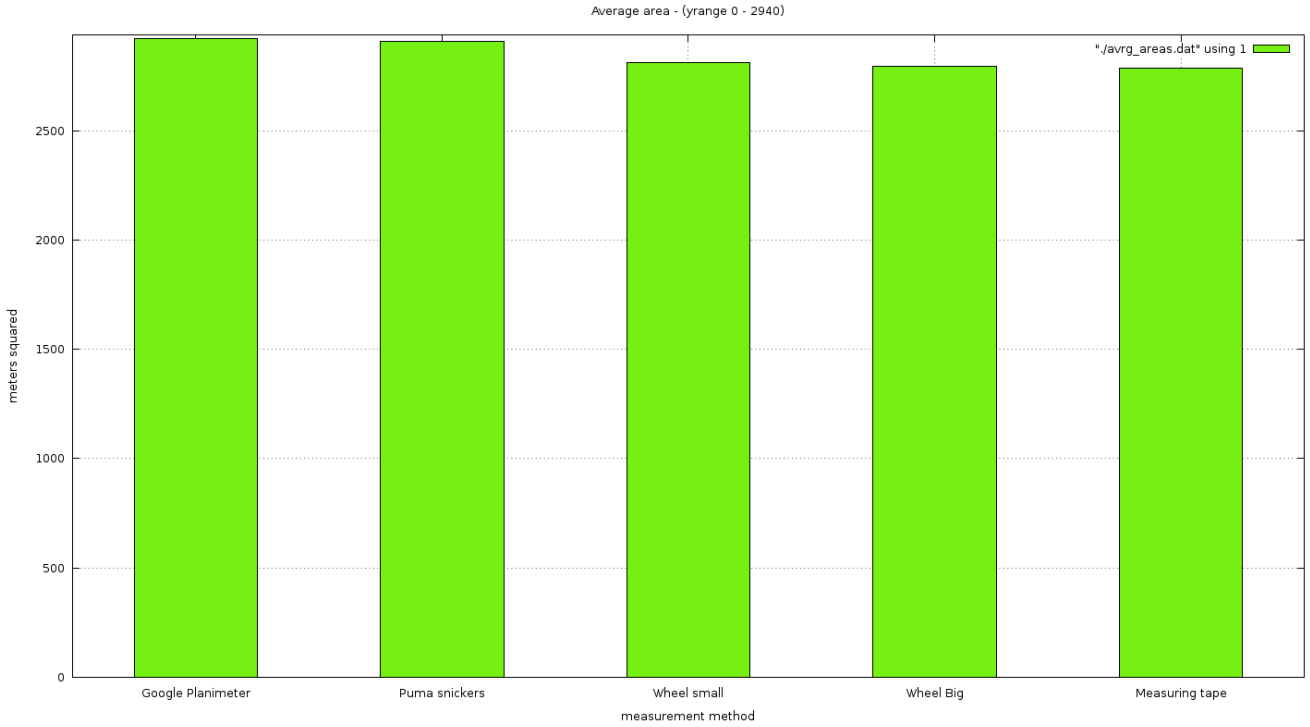
Wheel Big	Wheel small	Measuring tape	Puma snickers	Google Planimeter
Average area	**Average area**	**Average area**	**Average area**	**Average Area**
2795.7 m^2	**2811.0 m^2**	**2788.8 m^2**	**2911.8 m^2**	**2924.3 m^2**

As we can see the color coding still works. In this table I added a new area measurement technique which is Google Planimeter (http://acme.com/planimeter/) in which user selects desirable area with place marks and google calculates its area. I was not able to find the formula they use. My three measurements are here: (2923 m^2 + 2929 m^2 + 2921 m^2) / 3 = 2924.3 m^2.

I used gnuplot to visualize my results. Here is the basic script I wrote that generated my graphs:

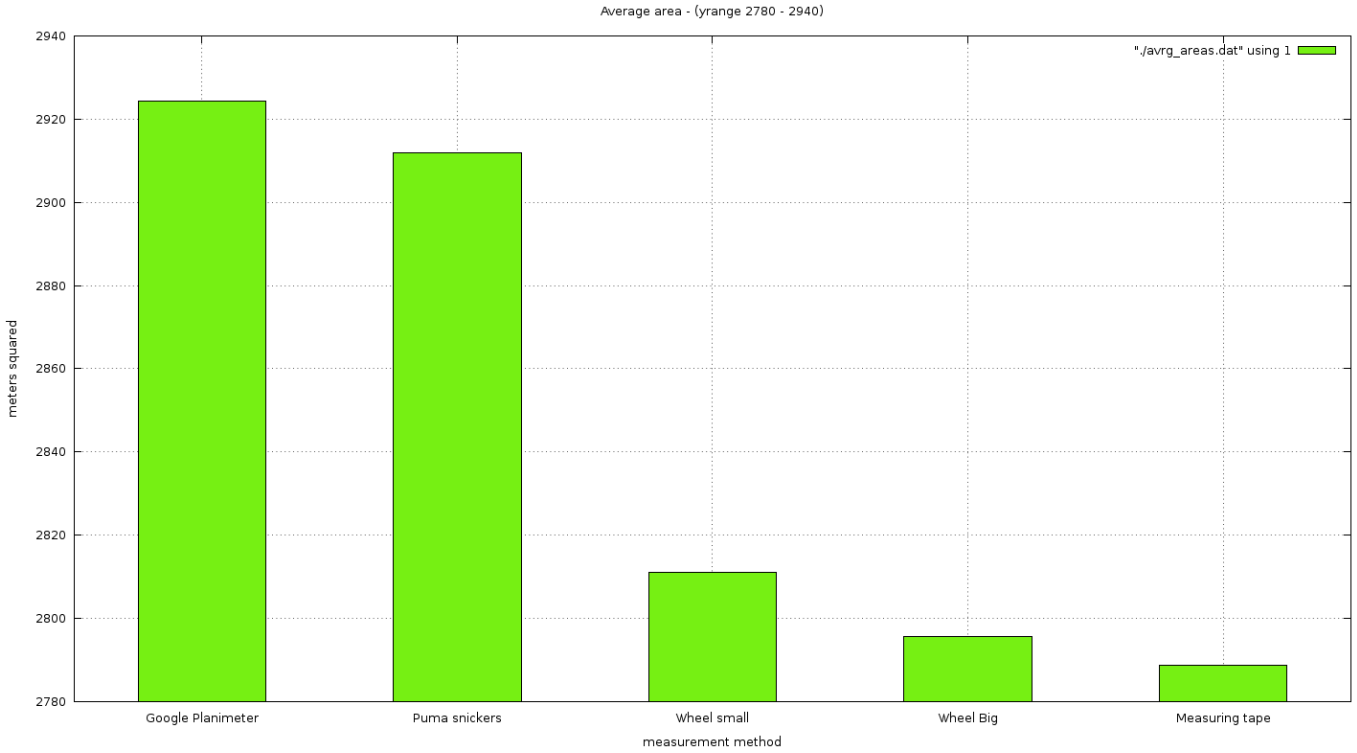
```
>> set title "Average area - (yrange 2780 - 2940)"
>> plot [-.5:4.5] "./avrg_areas.dat" using 1 with boxes lc rgb "green"
>> set boxwidth 0.5 absolute
>> set style fill solid 1.00 border lt -1
>> set xtics ("Google Planimeter" 0, "Puma snickers" 1, "Wheel small" 2, "Wheel Big" 3,
"Measuring tape" 4)
>> set ylabel "meters squared"
>> set xlabel "measurement method"
>> set grid
```

First graph I got:



We can see here that on scale from 0 - 3000 it is almost impossible to notice the difference.

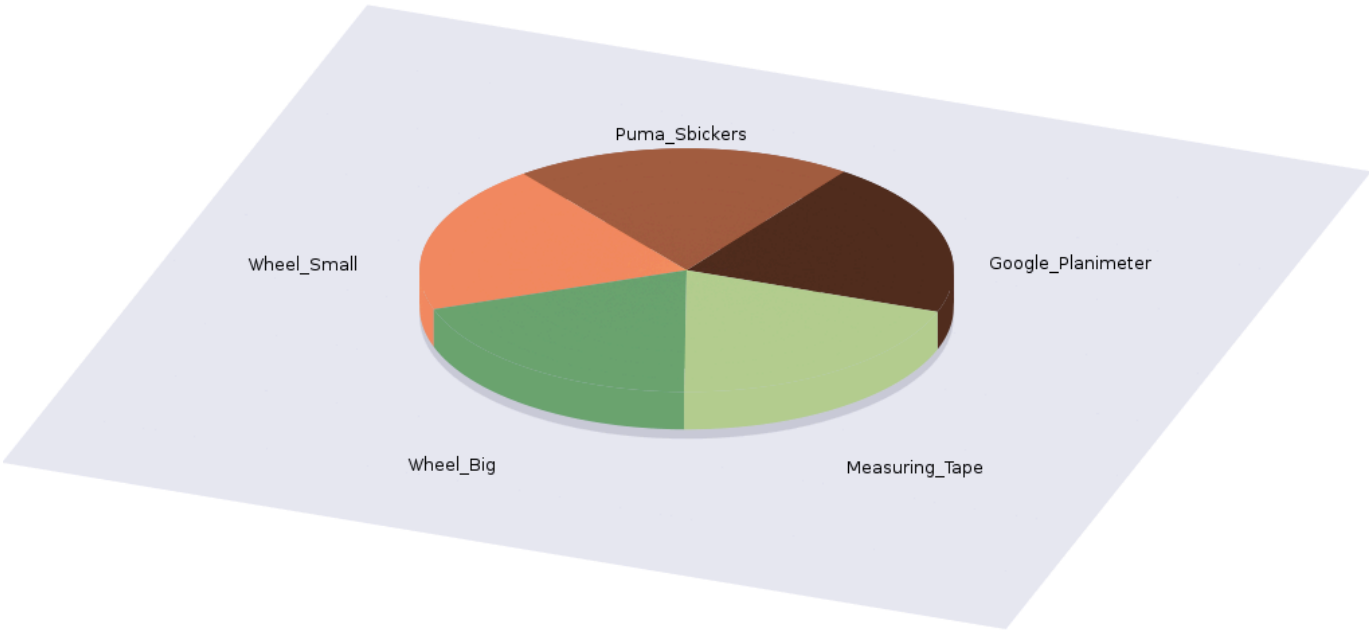
So in the next graph I changed the y range to be from 2780 - 2940. Here is what I got:
In this graph the difference is more than obvious and I can see clearly what Dr. Tufte is thinking when he talks about data manipulation and “cherypicking”.



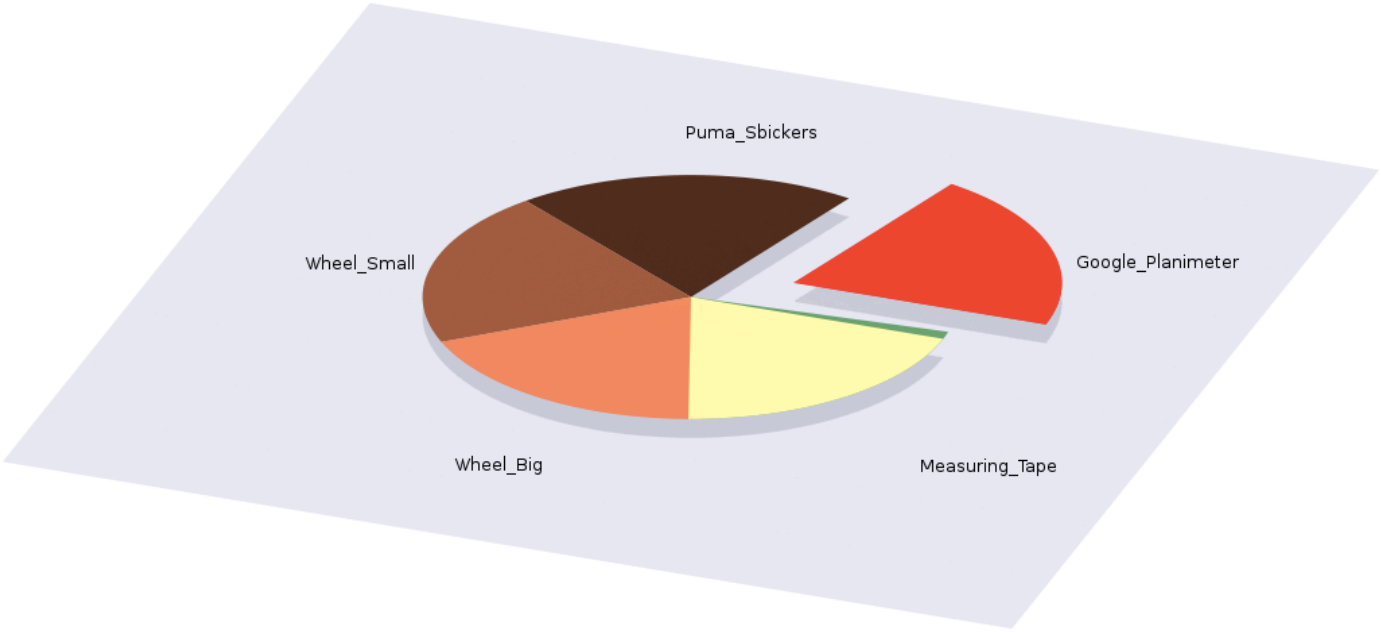
After first measuring I realized a few important details that could influence my measurements. Here is a list of things I did in order to eliminate them as much as possible:

* When we start measuring with measuring wheel its stick angle should be same at the beginning of measured distance and on the end of the distance.
* One should try to drive wheel as direct and as straight as much as possible.
* Clean side walk (measured area) as much as possible. My first measurement of NW - SW was 4% shorter on uncleaned sidewalk versus after I cleaned it.
* When using measuring tapeI made sure to have it as straight as possible. So I used stones and electric tape every 10m in order to make my measuring tape straight on the sidewalk and therefore lower the error.
* Before I started measuring I compared all 3 instruments by placing measuring tape on perfectly straight surface (NpYes lab) and using large and small wheel to measure its distance. I was surprised to learn that all 3 devices were extremely consistent when measuring the same length (Large and small wheel are made by the same company).

I was curious why pie chart is not a great way to visualize data. So I visualized my average areas in gnuplot using piechart. This is what I got:



I gave it one more try by lifting up the largest value. This graph shows it:

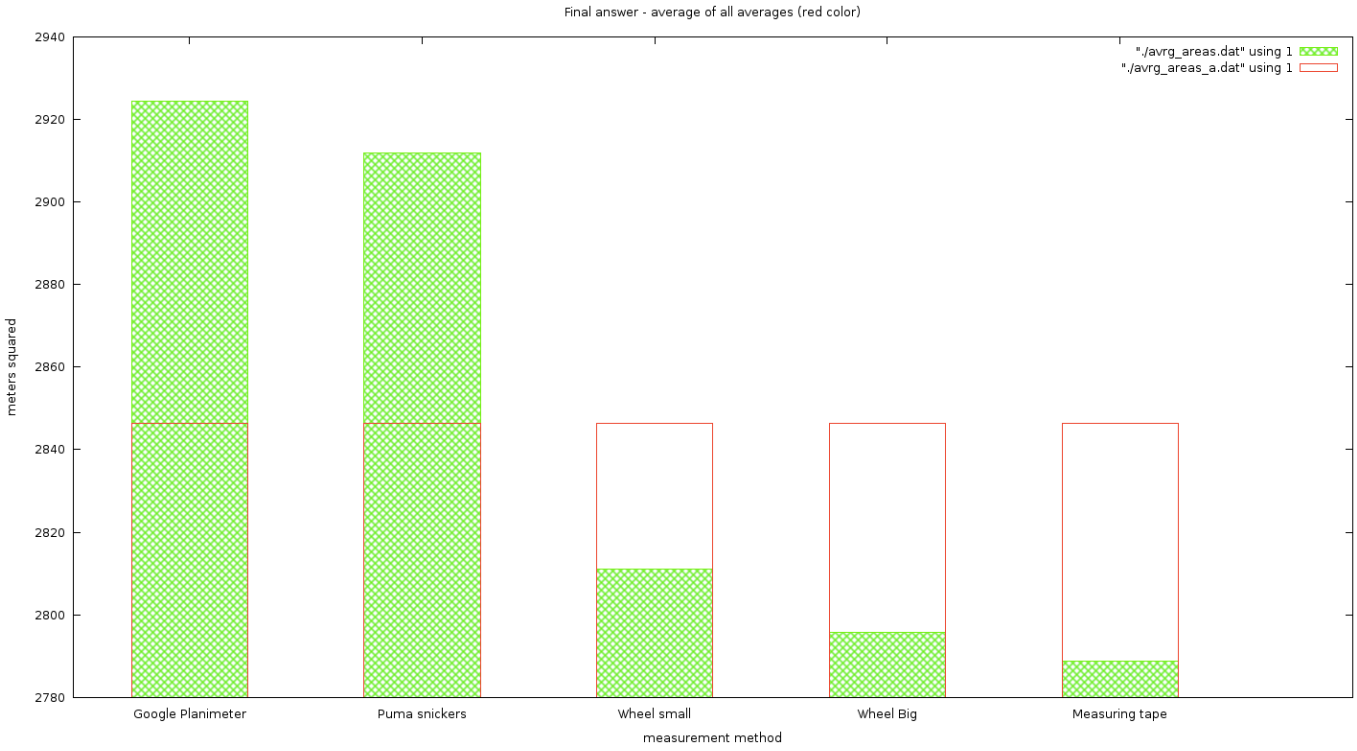


Still it was almost impossible to notice any difference in areas.

So I believe that my measuring method would be to measure area with as many tools as possible and than average their results. So When I sum up all of my average area I get:

$$2795.7\ m^2 + 2811.0\ m^2 + 2788.8\ m^2 + 2911.8\ m^2 + 2924.3\ m^2 = \mathbf{2846.32\ m^2}$$

This graph represents average in red color.



By using **physical** Planimeter I got three readings:

3140.1 m^2
3121.5 m^2
3084.3 m^2

The average is: 3115.3 m^2. One of the potential reasons why this measurement is significantly bigger than previous ones is because the map is dating back to 1980. Furthermore, SW - SE sidewalk looks very new.

I suppose that actual average for this lab is not very important. Space is cheap in Richmond, but this would drastically change in NY where every cm^2 is valuable and expensive.

For accurate measurements (3 times for every instrument), I walked distance of at least 2556 meters.