Programming Linear Regression Procedure for Analog & Digital Data

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Outline

I.) Background

II.) Introduction

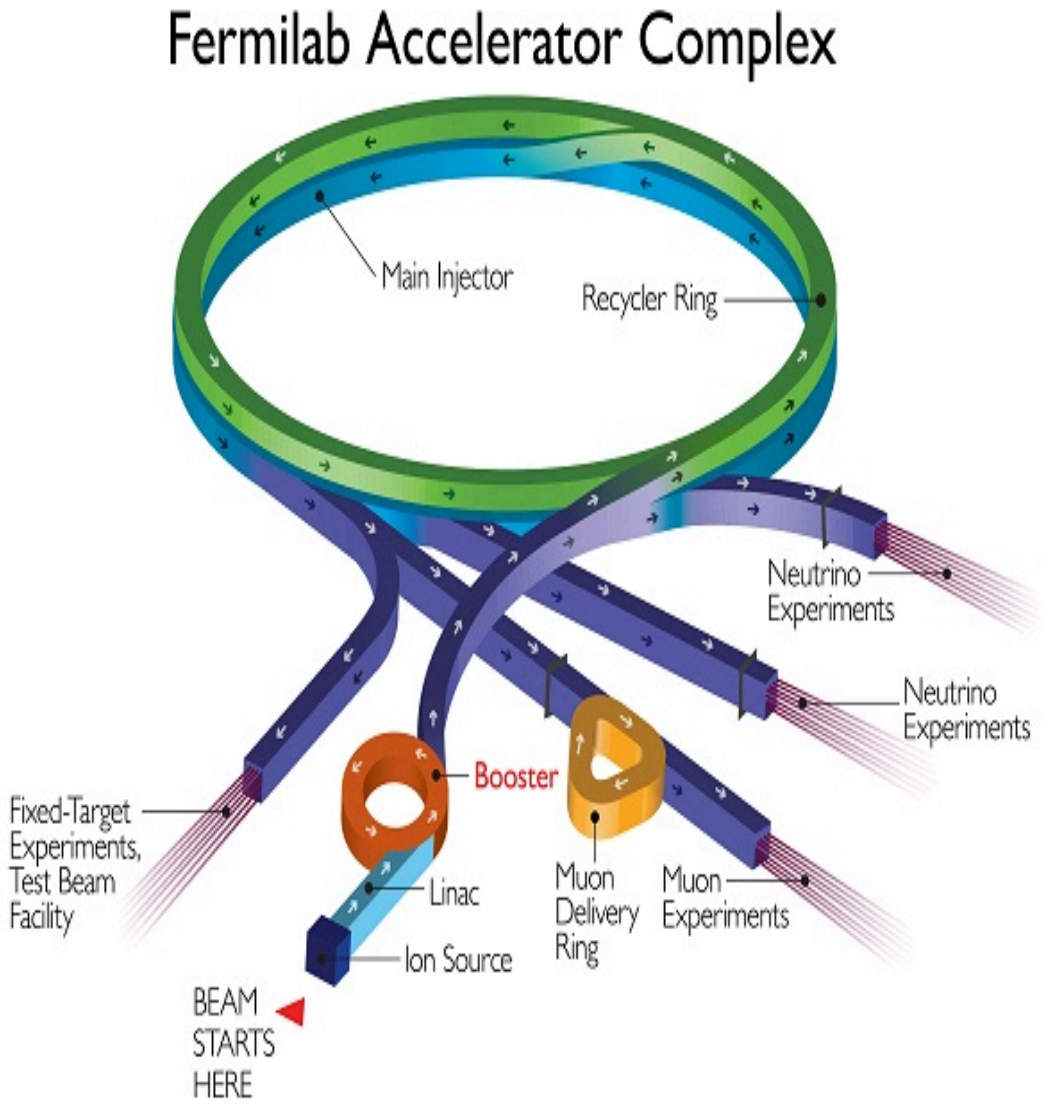
III.) Clock cycle & ADC card

IV.) Getting Connected

V.) Linear Regression & Modeling the Data

VI.) Key Takeaways, Issues & Future Work

Background: How does the Booster work?

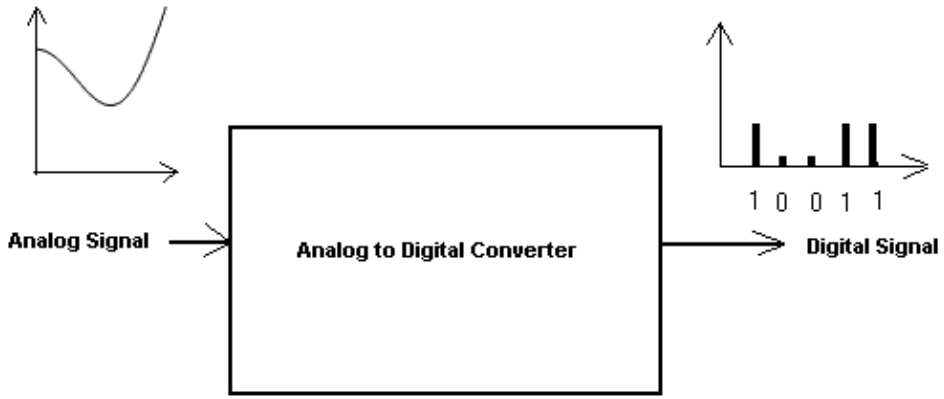


"The Fermilab Booster is a synchrotron accelerator with a circumference of 474 meters. Beam is injected into the Booster from the 400 MeV transport line which carries the 400 MeV beam output from the Linac accelerator. The Booster accelerates a proton beam from 400 MeV to 8 GeV in less than 33 milliseconds for the Main Injector accelerator. Booster also provides beam for the MiniBooNE experiment and the NuMI facility and MINOS experiment."

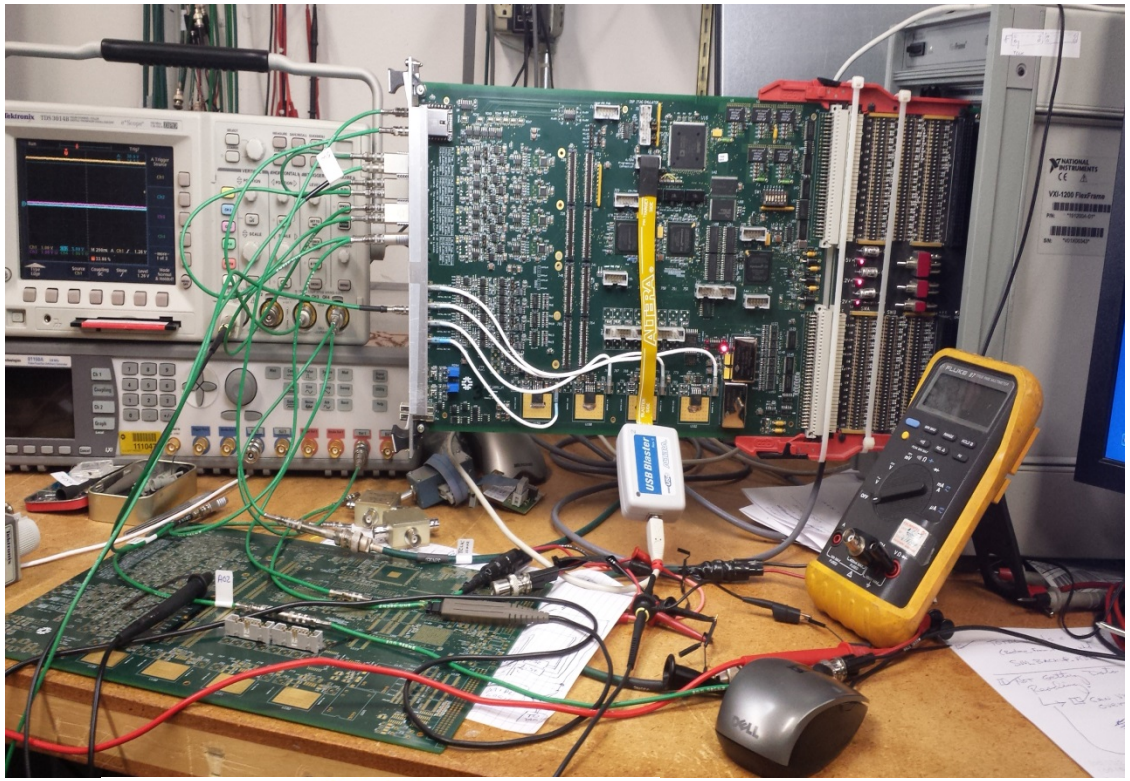
Introduction

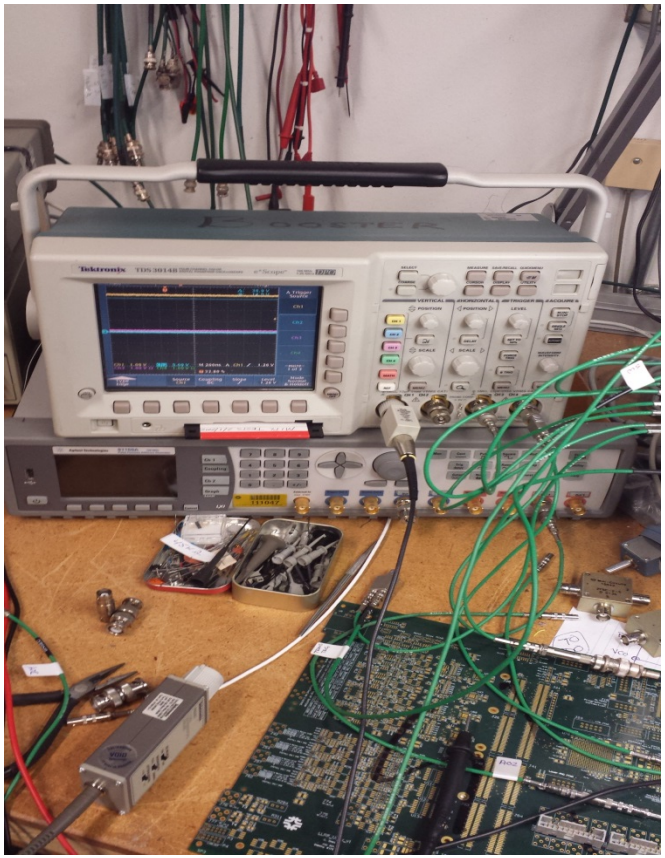
Problem? Why do this?

The beam cycle in the booster is set to be in specific places at precise times. The clock cycle keeps measure of this. However, because the beam is read as an analog occurrence adjusting with precision is not feasible until the analog signals are converted to digital data. Designing a program using least squares fit to convert the signals will allow us to finely adjust what we need to for the beam operations.



Clock cycle and ADC card





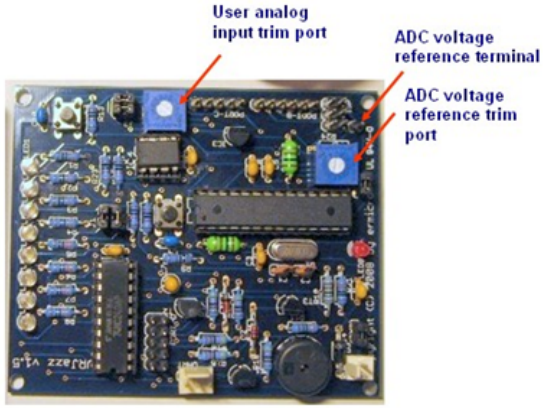
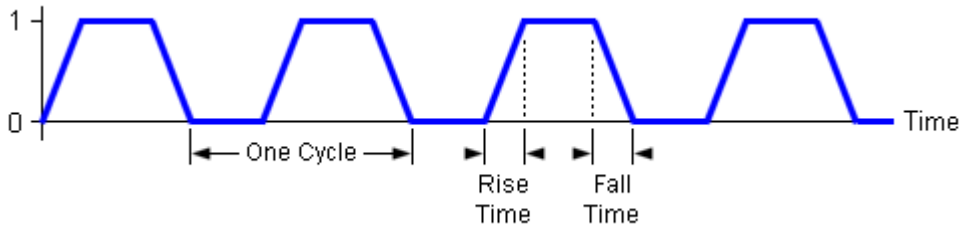


Figure 1



https://www.youtube.com/watch?v=rch2HAtGaMQ

Getting Connected

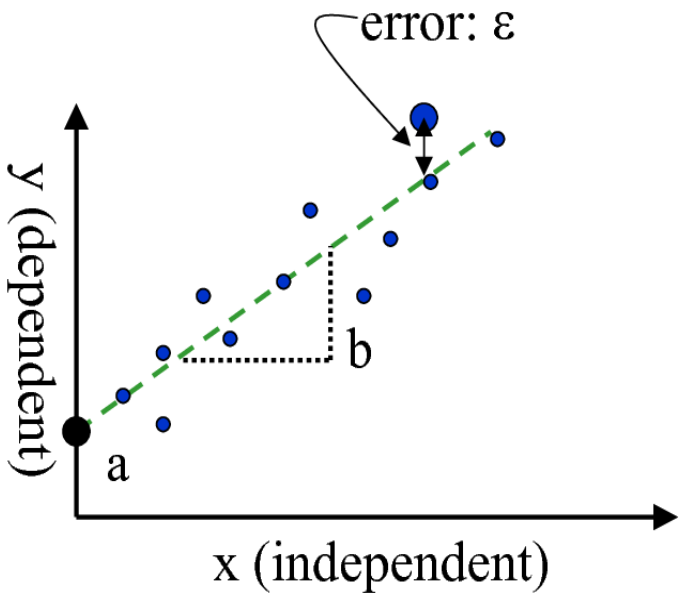
- SSH
- Outland.fnal.gov
- Nova.fnal.gov
- VXIDSP
- Code
- BIrfd3
- Minicom

Simple Linear Regression

Simple linear regression models the relationship between an independent variable (x) and a dependent variable (y) using an equation that expresses y as a linear function of x, plus an error term:

$$y = a + bx + e$$

$$a = \frac{n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{n\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2}$$



x is the **independent** variable

y is the **dependent** variable

$$b = \frac{1}{n}(\sum_{i=1}^{n} y_i - a\sum_{i=1}^{n} x_i)$$

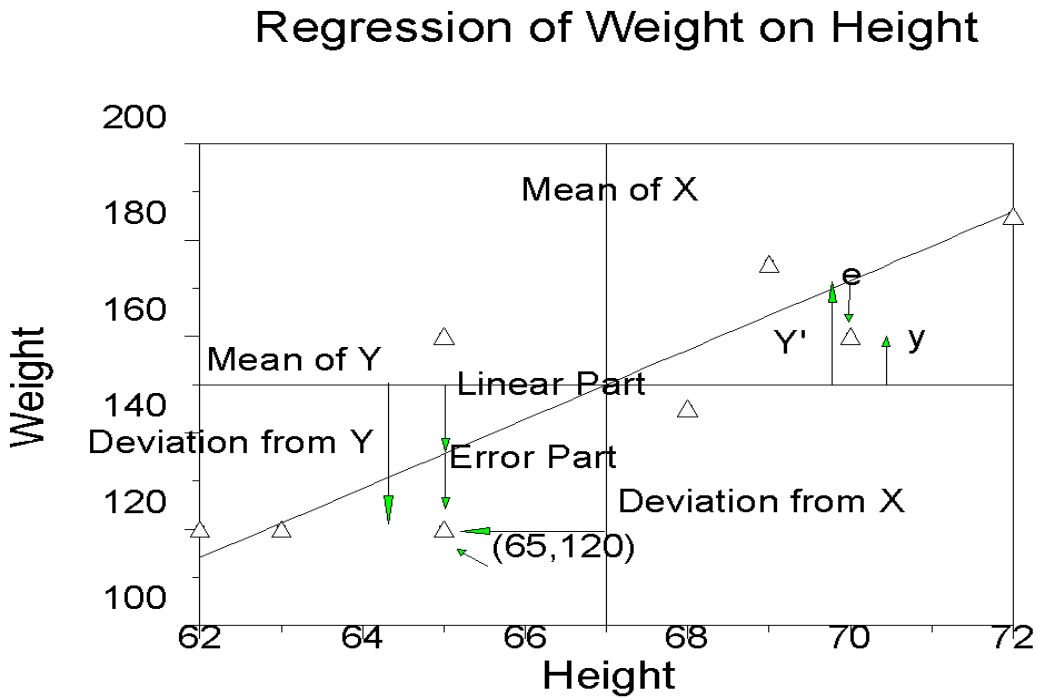
b is the **slope** of the fitted line

a is the **intercept** of the fitted line

e is the **error** term

In everyday terms…

- Linear regression is a mathematical formula used to find the relationship between two occurrences.
- For example, correlation between weight & height….



Writing Code

I.) Needed to create data file, header file, one program to read in data, and one program to perform operations

II.) Had to be written in C over the scientific Linux environment

III.) Modified Best Fit equation and code to work with analog and digital data.

Linear Regression

Applications Places System

linreg.c - /export/home/megan/code/vxidsp/ (on nova.fnal.gov)

File Edit Search Preferences Shell Macro Windows

```
#include <vxWorks.h>
#include <vxLib.h>
#include <sysLib.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <math.h>
#include <time.h>
#include <taskLib.h>

static float sqrarg;
#define SQR(a) (sqrarg=(a),sqrarg*sqrarg)


void fit(x,y,ndata,a, b, siga, sigb, chi2, q)
float x[], y[], *a, *b, *siga, *sigb, *chi2, *q;
int ndata;


{
        int i;
        float t,sxoss,sx=0.0,sy=0.0,st2=0.0,ss,sigdat;

        *b=0.0;

            for (i=1;i<=ndata; i++) {
                sx += x[i];
                sy += y[i];
            }
            ss=ndata;

        sxoss=sx/ss;

            for (i=1;i<=ndata;i++) {
                t=(x[i]-sxoss);
                st2 += t*t;
                *b += t*y[i];
             }

        *b /= st2;
        *a=(sy-sx*(*b))/ss;
        *siga=sqrt ((1.0+sx*sx/(ss+st2))/ss);
        *sigb=sqrt (1.0/st2);
        *chi2=0.0;

        printf ("A is: %p %f, \n", a, *a);
        printf ("B is: %p %f, \n", b, *b);

           for (i=1;i<=ndata;i++)
               *chi2 += SQR(y[i]-(*a)-(*b)*x[i]);
           *q=1.0;
           sigdat = sqrt((*chi2)/(ndata-2));
           *siga *= sigdat;
           *sigb *= sigdat;

}
```

Testcode

Applications Places System

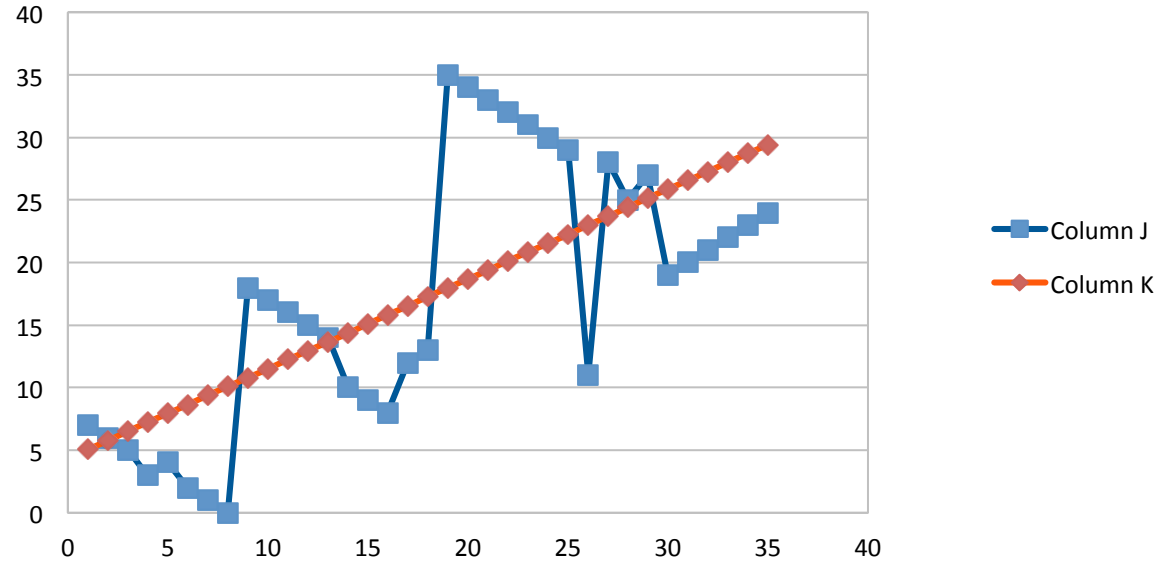
testcode.c - /export/home/megan/code/vxidsp/ (on nova.fnal.gov)

File Edit Search Preferences Shell Macro Windows

```
 1 #include <vxWorks.h>
 2 #include <vxLib.h>
 3 #include <sysLib.h>
 4 #include <stdio.h>
 5 #include <stdlib.h>
 6 #include <string.h>
 7 #include <math.h>
 8 #include <time.h>
 9 #include <taskLib.h>
10 #include "linreg.h"
11
12 /**
13  * Author: Megan D. Williams, University of Arkansas Pine Bluff SIST '14
14  * Created: 07.22.2014
15  *
16  * The testcode function reads in data from voltArray and digArray relating to
17  * the analog/voltage info in and digital code out.
18  * The fit function then takes the input from voltArray and digArray and
19  **/
20
21
22
23 int testcode(void)
24 {
25
26     float voltArray[36], digArray[36];
27     int i, ndata=35;
28     float a, b, siga, sigb, chi2, q;
29
30     FILE *myFile;
31     myFile = fopen("/remote/testdata.csv","r");
32
33     /*read file into array*/
34
35
36     for (i = 1; i <= ndata; i++)
37     {
38         fscanf(myFile,"%f,%f",&voltArray[i],&digArray[i]);
39     }
40
41
42
43     for (i = 1; i <= ndata; i++)
44     {
45         printf("Number is: %f,%f\n\n", voltArray[i],digArray[i]);
46     }
47
48     fit(voltArray,digArray,ndata,&a, &b, &siga, &sigb, &chi2, &q);
49
50
51     printf ("A is: %f,\n", a);
52     printf ("B is: %f,\n", b);
53     printf ("Siga is: %f,\n", siga);
54     printf ("SigB is: %f,\n", sigb);
55     printf ("Chi2 is: %f,\n", chi2);
56     printf ("Q is: %f,\n", q);
57
58
59
60   fclose(myFile);
61   return 0;
```

Results:Modeling the data with LINEST

- Column J represents the data input
- Column K represents the output from the program
- What do these lines show?



Issues & Solutions

- Working in unfamiliar environment
- Access & permissions (Getting kicked out everyday!)
- Time constraints versus best method (FPGA, VDHL)

Recap: Key Takeaways & Future Work

- Booster Beam…
- Keeping Time in the Booster…
- Analog to Digital…
- Programming the for the Card…
- Linear Regression helps by…
- Continue adjusting code…
- Next steps (setting DPOT & DAC), revision with sequence

References

- C. Drennan, Interfacing to the Booster BLM Upgrade Integrator/Digitizer VME Module. Fermilab BEAM-DOCS-3780, February 2011.
- C. Drennan, Booster Beam Loss Monitor Data Acquisition and Presentation Specication. Fermilab BEAM-DOCS-3723, December 2011.
- Press, William H.. *Numerical recipes in C: the art of scientific computing*. Cambridge [Cambridgeshire: Cambridge University Press, 1988. Print.
- http://www-ad.fnal.gov/proton/booster/booster.html

Acknowledgements

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Fermilab/DOE

???????Questions??????