Handwriting Recognition Pen

[For economically disadvantaged students]

Motivation for project

Few years back we went to a rural school during National Social Service(NSS) camp to teach rural children.

I was awestruck seeing their passion to learn something new and interesting.

Only thing which was between their dream and reality was the barrier of money.

I think that was day was when I started wishing If I could work for their well being.

I could still remember the mere happiness of face of a kid when I taught him to write alphabets.

How can we help financially poor students to achieve their dream?

Proposal

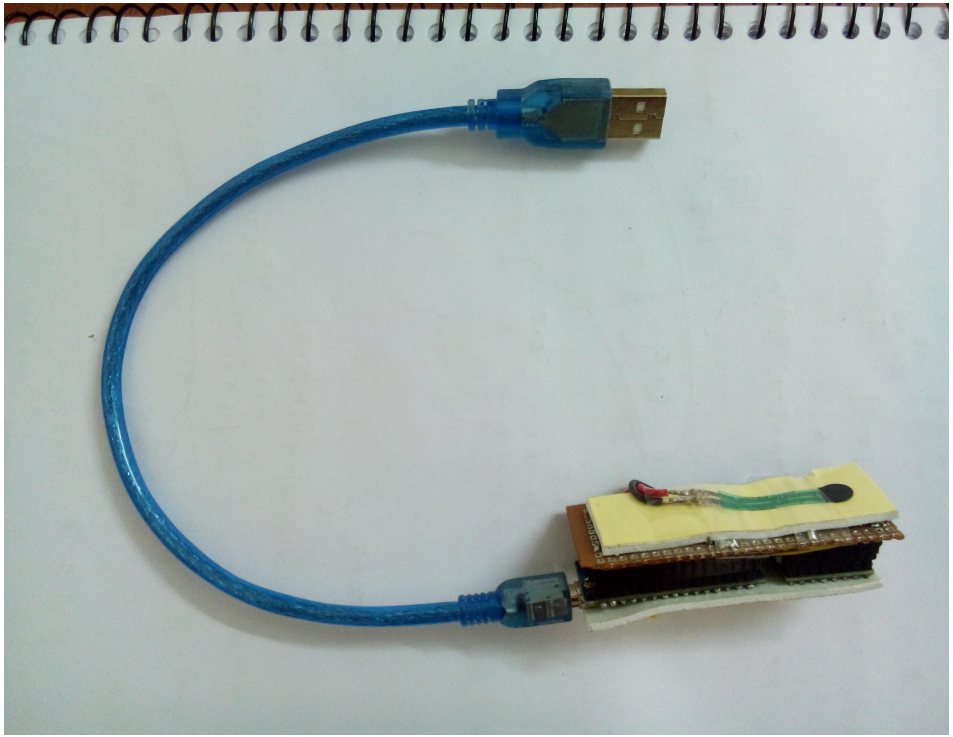
A handwriting recognition pen which could help them in studies by

- Detecting wrongly spelt words and give instant suggestion
- Detect the calculation error
- A class where all students are connected to a central system (app possibly) and teacher is fully aware of who is committing what mistake.

Work to be completed for this project

- Develop a small and cheap PEN like module
- Reduce the cost by eliminating the use of camera or special paper or ink compared to commercially available one.
- Develop a learning algorithm which could learn to recognize the owner as handwriting of every individual is different.
- Make it recognize Multiple character at a time.

Electronics part of PEN



Equipments used:

- Gyroscopic Sensor(MPU6050)
- Accelerometer(ADXl 335)
- Force Sensitive Resistor
- Micro_controller(Arduino Nano)

Overall cost: Rs 1200 ($20)

Research: Problem Faced & How they helped to Overcome it.

Feature Selection

Problem

The first Model for classification I applied was Logistic regression with multiple classes but the features I took as an input were directly acceleration points and even that trimmed to certain limit.

That model under fitted due to lack of good features.Also feature selection was necessary as the data for letter were not of same length

Solution

Jeen -Shing Wang et al.[7] & Shiqi et al. (2008)[3] showed how feature from a **time varying data could be quantized.**

R.Moreau et al. et al.[2] approach to use features like curvature inspired the idea to use orientation data along to find **Curvature and Torsion**. Also after extraction of **Pressure variation** made on grip were specific to the letter written. The use of quaternions by **R. Moreau et al.** helped in finding the torsion of trajectory.

Selection of Model and Length predictor

The following choices were available for classification problem:

1. Dynamic Time warping Algorithm proposed by **Shiqi et al. (2008**)[3]
2. Hidden Markov Model proposed by **Jeen -Shing Wang et al.[7]**
3. Neural Network proposed by **Jeen -Shing Wang et al.[7]**
4. Long Short-term Memory **proposed by Alex Grave[4]**

I chose Neural network due to its ability to fit natural data very powerfully

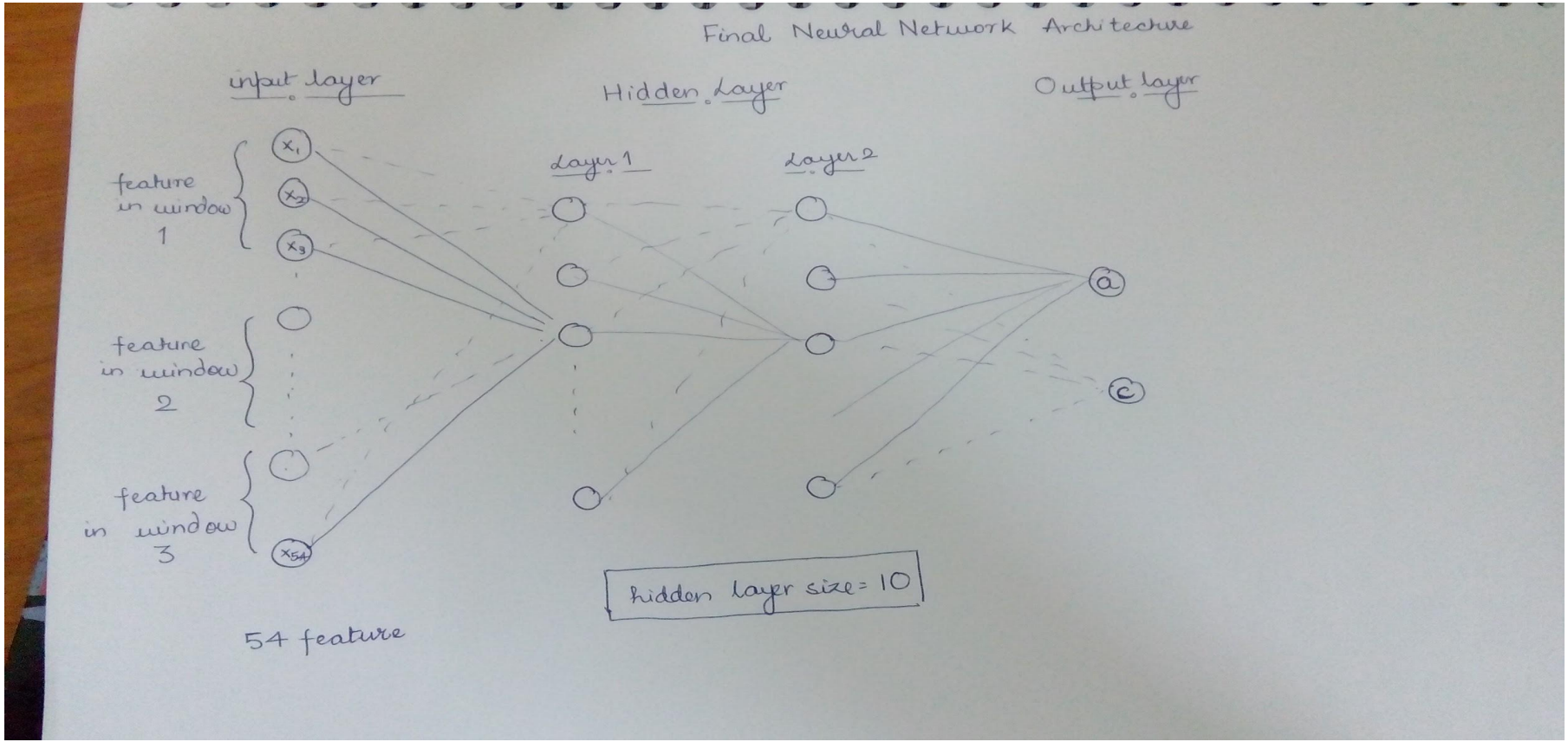
The problem of variable length of data for each character was solved by first proving that **the net acceleration data and corresponding length of data (time equivalent) are Bivariate Normal** by doing experiment.

Then the conditional distribution of

P(length =some value|given acceleration is some observed value)

Was used to determine the 65% confidence interval for our length prediction for a character

The(final) Neural-Network Architecture



Length Predictor

The **time variance of length of data obtained for a particular character was different** because of difference in speed of writing which made it difficult to find transition from one letter to other.

So I experimented to find the **correlation between net acceleration** and **length of data** obtained for a character

To test the hypothesis I conducted an experiment:

Procedure: A person will write a word (**in our experiment "abcdefghijklmnopqrstuvwxyz"**) and once he finish writing he will leave the tip of Pen loose which will reduce the pressure from pressure sensitive resistor which is set at a threshold (**in experiment 670**) to stop the data flow if pressure reduces to a certain limit. In this way data of acceleration and length were received. On analyzing with an **online web application[6]** by ***Selcuk Korkmaz*** *et al.* the data was found to be Bivariate Normal.

Testing and experimentation

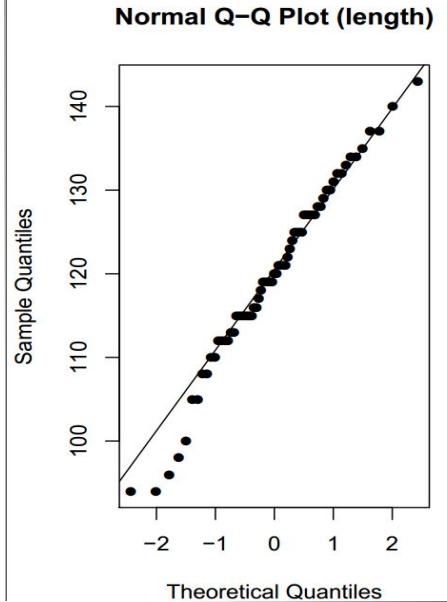
The unbiased test of F1_Score was conducted to select the Model Parameters like **Number of layers in Neural Network**, **Number of neuron units in each layer** and **regularization parameters.**

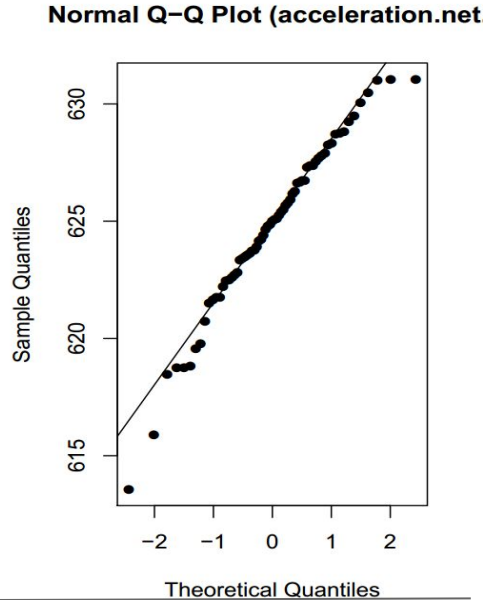
F1_score=(Precision*Recall)/ (2*Precision+Recall).

Precision= Correctly labeled class1/ (Correctly labeled Class1+Falsely labelling other classes to Class 1)

Precision =Correctly labeled class1/ (Correctly labeled Class1+Falsely labelling other Class1 to Class other class)

Online application along with self generated probability fitting plot was used to test the multivariate Normality of data.

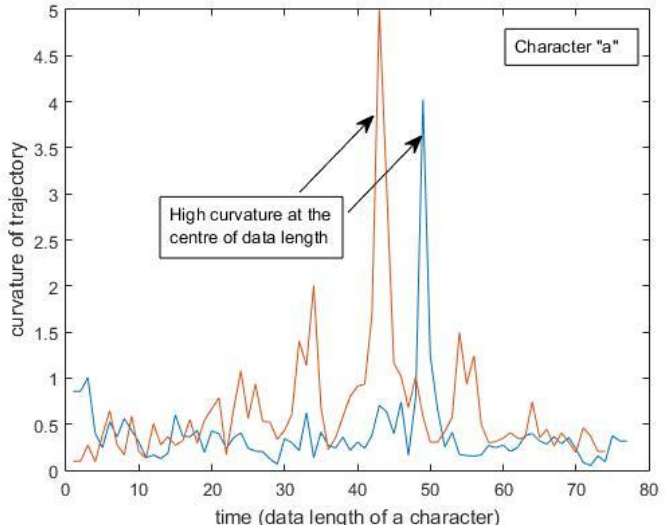


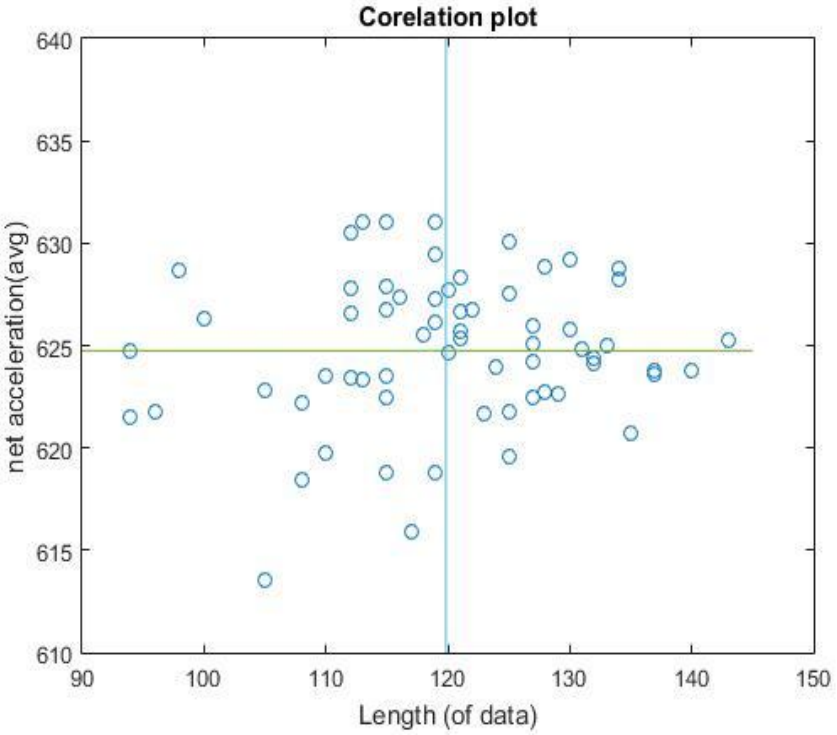


Some Experimental Results and observation

Variation of test parameters with layers

	layer1	layer2	layer3	layer4	layer5	layer6
precision	0.86	0.95	0.5	0.52	0.525	0.525
recall	0.926	0.975	1	1	1	1
F1_Score	0.89	0.9	0.68	0.68	0.68	0.68



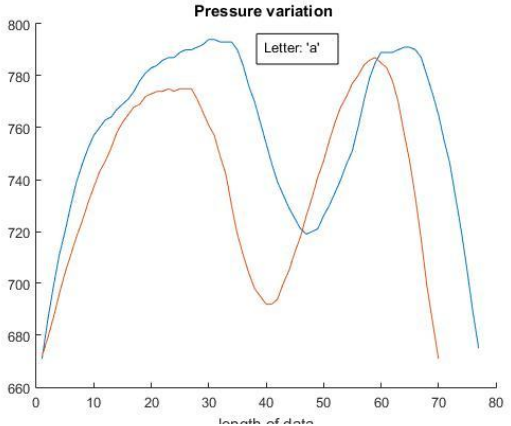


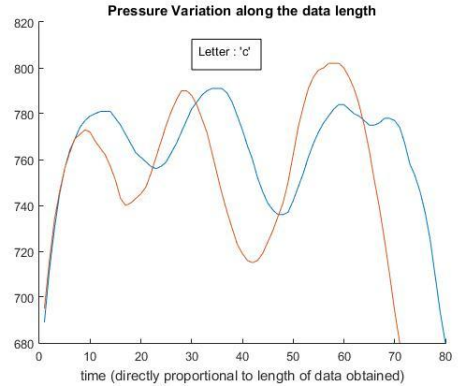
Discovery: Well I found out Few things important !!

1. The net_acceleration and length of data for a character are normally distributed and also they are individually normal.
2. Inspite of negative correlation (as expected) between the standard deviation of acceleration and data they are not normally distributed.
3. The curvature I calculated is supported by visual plot which gives clear indication of curvature being high where the general characteristic of letters is curved.

Important Results: continued

The **pressure variation** (measured by mounting a pressure sensitive resistor) showed special characteristic plot for different letter. From which we can conclude that there is variation of pressure at different position at differnt section of trajectory for two characters.





Conclusion:

The method I used for a character recognition (Neural Networks) has F1 score .9 and the efficiency of Length predictor was extraordinary which predicted(for data see next slide) the confidence interval for length for one character.The confidence percentage determined how much Type 1 error we will commit while finding the bound.

(eg If my confidence percentage is 90 % then i have 10% chance to commit type 1 error)

(Type 1 error=probability of length being outside the bound given by predictor)

	actual length 1		actual length 2		predicted bound 1		predicted bound 2		number of character tracked	percentage confidence
test case	character	position	character	position	lower	upper	lower	upper		
aa	98	98	93	191	70	86.18	139.74	155.69	3	60
aa	74	74	73	147	69.51	85.42	139.69	155.64	2	60
aa	87	87	81	168	69.79	85.73	145	155.31	2	60
cc	80	80	90	170	70.08	86.03	139	155	2	65
cc	84	84	58	142	70.62	86.57	140.6	156.7	2	65
cc	66	66	74	140	69.01	70	154	170	2	65
ac	65	65	81	146	64	91	155	182	2	85
ac	74	74	79	153	64.8	91.62	128	155	2	85
ac	64	64	80	144	64	91.5	130	156	2	85
ca	76	76	67	143	61	93	131	162	2	90
ca	84	84	81	165	62.5	94.3	134	165	2	90
ca	85	85	65	150	61	93	133	165	2	90

Here Position refers to the index of length in Length_data.

How my work will help in this area

The cost of commercially available handwriting pens are too high as they use shopisticated cameras on pen tip or special papers or ink.

My work in this field could give them a way to do handwriting recognition using cheap yet powerful sensors and feature I extracted out were very good and matched with real world.

Also length predictor which was discovered by me will give them accurate interval to find character transition in gesture.

Future Work: I am excited

1. Make the predictor to recognize complete alphabet (just scaling up).
2. Improve the length predictor by scaling it up to multivariate conditional distribution as it must be depending on something else other than just acceleration as there is no great linear correlation between them (as seen in plot earlier) even when it was expected.
3. Scale it up to recognize number and predict the calculation.
4. Bring it in real world to poor children for least possible cost.