Comparative Study of Forces Involved in Different Styles of Handwriting

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***Abstract*—The project involves the usage of tactile sensors to study the forces applied on thumb, index and middle fingers for two different styles of handwriting - cursive and non-cursive. A comparative study is made based on the finger forces by quantitative analysis using MATLAB. The result of this paper shows the non-cursive style of writing requires forces below 7N whereas the cursive style takes forces more than 7N, which might vary from person to person. An intelligent classification technique, SVM (Support Vector Machine) has been used to classify the forces between the two styles of writing. The result can be applied in choosing the appropriate surface forces for a prosthetic hand.**

***Index Terms*—forces on fingers, handwriting styles, comparative study, quantitative analysis, SVM based finger force analysis, prosthetic hand**

I. Introduction

Tactile sensor usually refers to a transducer that is sensitive to touch, force, or pressure. A sensor's sensitivity indicates how much the sensor's output changes when the measured quantity changes. Tactile sensors are employed wherever interactions between a contact surface and the environment are to be measured and registered. Such sensors can be used to test the performance of all types of applications such as medical devices, dynamic automotive testing and ergonomics.

Biologically inspired tactile sensors might detect both the distribution of pressures, and the pattern of forces that would come from pressure sensor arrays and strain gauge rosettes. The project involves the usage of one such sensor, "Finger Tactile Pressure sensor" (Finger TPS) ,to reliably quantify the forces applied by the human fingers, that include but not limited to index, thumb and middle finger for two different styles of handwriting - cursive and non-cursive.

The paper also illustrates new aspects of the applicability of Support Vector Machines (SVMs) in knowledge discovery and data mining. Kernel selection tool is used for classification and regression problems using support vectors, producing normalized results for multiple samples.

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II. Literature Survey

[1] proposed an effort to improve the sensation of an artificial limb by using ten pressure sensors on various locations on the fingers to guide a human. The experiment was carried on two children who were below the age of 9.Pressure sensors were embedded at the tip and bottom of the fingers. The design was aimed at providing comfort to the individual using it. Two pressure sensors were placed at each finger. Cumulatively, ten sensors were used. This was designed by making a balanced compromise on the mechanical limitations and the cost. Tactical pressure sensors were used to measure the pressure from the human hand. By carrying out the experiment, it was found that the force profile varies from individual to individual and also on the way of grasping.

[3] projected a design of a cost effective artificial fingertip and a system for recording individual fingertip forces. Force sensing resistors were used as the main component. The sensors were inserted on the distal phalange of both thumb and index finger of an adult. A computer system was integrated, that operates in real-time to take accurate measurements of fingertip forces during pinch grip. The voltage data from the sensors and the force data from the dynamometer were acquired by a computer program. Using the data from sensor and dynamometer, a curve corresponding to the curve obtained by the dynamometer is obtained. The system was automatically able to calibrate the range of forces in the sensors with an acceptable level of accuracy. Test was performed on standard experiments of pinch grip, and was integrated into a robotic system. It was found that the force sensor presents a minimum inter-subject and inter-trial variability, and a good inter-trial repeatability.

[4] proposed a model of a tactile force sensing glove to measure the force applied on a fetal head during childbirth. Five piezo-resistive sensors were strategically placed in the glove to measure normal forces applied to the head. Sensors were placed such that maximal contact

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between the head and sensors was achieved. Real-time reading of the sensors was done by a computer. Each sensor was calibrated to determine the relationship between compression and voltage output. A known force was applied to the sensor and the output voltage was read. A prototype version was developed and tested with multiple birth simulations.

III. Sensors

As the writing is effective on three fingers, we need to recognise the minute force variation on each location. The sensor which is preferable for measuring is touch sensitive sensor. Tactile sensor is one such touch sensitive sensor that is widely used for various applications.

A. *Principle of Sensor*

In this sensor, differential information between the two strain gauges is collected as output signal. When the sensor is slid over the surface with the uniform curvature, resistance changes of the two strain gauges are approximately equal since the sensing area has uniform pressure distribution. When the resistance changes in the two strain gauges, an output signal is produced. Output signals from the sensor are sent to a PC through a strain gauge amplifier and an A/D converter.

Figure 1. Apparatus - Sensor Kit

B. *Structure of Sensor*

The sensor is 12 mm square and 2.5 mm thick. The sensor is composed of a thin rubber sheet that is 0.5 mm thick and a silicone rubber with a void in the centre. On the centre of the rubber sheet, two strain gauges (gauge length: 1 mm, grid width: 1.5 mm) are attached point-symmetrically. Furthermore, Teflon tape is attached on the rubber sheet in order to reduce the influence of friction. The bottom of the sensor is the sensing area. The user puts his/her finger on the silicone rubber of the sensor and slides the sensor over the objective surface. The sensor is very soft and flexible. The sensor can be applied to the curved surface as well as the plane surface. Furthermore, the pressure applied by the finger does not convey directly to the strain gauges on the sensor because of the above mentioned structure. The applied pressure conveys to the silicone rubber and the relatively uniform pressure is applied to the sensing area including the strain gauges.

IV. Methodology

In this experiment, 10 different individuals are made to write the test data in both cursive and non-cursive style of writing using highly sensitive, capacitive-based pressure sensor namely Finger TPS. The forces are measured using Finger TPS as shown in the Figure 1. The finger TPS pressure sensors are fitted to ring finger, middle finger and thumb points where there is a direct application of force [5]. The position of sensor placement remains the same for each person but the orientation is decided based on the way pen is held by the individual.

Figure 2. Sensor placement on thumb, index & middle fingers

Precise force data, videos and images can be captured and displayed in real time via Chameleon TVR Software(A custom made software for Finger TPS Sensing system), which has versatility in recording time-series, average and peak force measurements. These sensors can be remotely connected to the PC for data recording and analysis either through a cable (USB) or Bluetooth.

A. *Experimental Procedure*

- Finger TPS system is interfaced via USB to the PC.
- Calibration must be done for each sensor at their respective positions in hand using Chameleon software.
- With sensors on hand, each individual is made to write the test data in both cursive and non-cursive style.
- Calibration is done during each individual study.

V. Analysis

The force data pertaining to each finger along with the duration of the experiment is imported to MATLAB. The user defined function removes the initial offset with respect to time so as to equalize the time of starting for two different styles of writing. Later, the range of error free data is calculated based on data points. This range shall be used for the computation of the mean value for forces on each finger and total force as well. This filtered data is used to classify between the two styles using SVM. The corresponding plots are generated simultaneously. The above process is repeated for 10 such subjects. One such plot describing the mean force on each finger and total force for a subject is shown in Figure 3.

From the repetitive process for 10 different subjects, it is found that the forces on thumb, index and middle finger due to cursive style of writing are 4.9N, 2.2N and 2.6N respectively. Similarly, the forces on thumb, index and middle finger due to non-cursive style of writing are found to be 2N, 1N and 1.7N respectively.

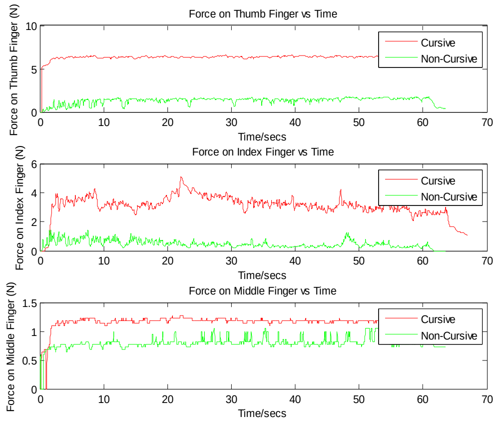

Figure 3. Forces on thumb, index and middle finger

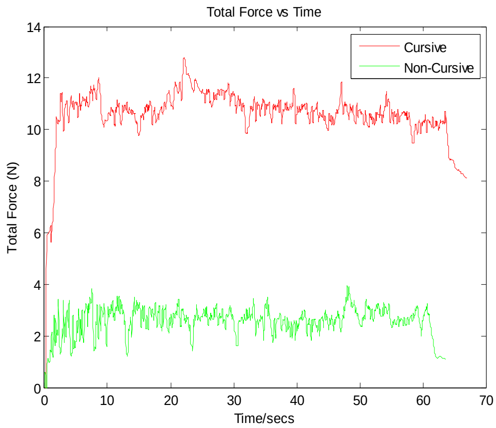

Figure 4. Total force plot for cursive and non-cursive

This mean force analysis pertaining to each finger may vary from person to person based on the way they hold the pen [6]. As expected, the force on thumb appears to be the highest. However, one shall observe an interesting result wherein the force on middle finger is higher when compared to that of the index finger contradicting the normal perception. Tabulation of the results from the analysis is shown below.

TABLE I: FORCE ANALYSIS

Finger	Mean Force - 10 Subjects (in N)	
	Cursive	Non-Cursive
Thumb	4.9	2
Index	2.2	1
Middle	2.6	1.7
Total Force	>7	<7

The total force used by a person to write using cursive style is normalized to any value greater than 7N while those values that fall below 7N shall be classified into non-cursive style of writing.

VI. DATA CLASSIFICATION

For differentiating the two styles of writing it is necessary to classify the samples. SVM is used for classifying cursive and non cursive data. The data classification by this technique needs data in appropriate format i.e. in a data set format. It is required to frame data set before it is taken to SVM data classification. Below sub section will cover the creation of data set, SVM analysis technique and interpretation from the analysis.

A. Description of the data sets

The data obtained from sensors has been split into two data sets. The first data set is the refined cursive style data where as second data set is obtained as the non-cursive style data. The data set is created with the dimension of 10 by 6000. The data set is framed as matrix that includes, retrieved force values as columns and subjects as rows i.e. for each subject the forces values are arranged as row vector. Both data sets proved to be relatively easy to separate.

B. SVM classification

After pre-processing, the total force analysed gave an approximate classification of writing style. Although the separation of the data is easy, the problems present several features of difficulty, one such that is data differently distributed. An improved classification technique (SVM) will help in analysing such distributed.

The process of SVM involves identification of a linear/ non-linear plane for discriminating two classes with given data set. SVM needs label data set, training data set and testing data set for data classification [7]. The technique formulates weighted matrix to create the two hyper planes by calculating functional margin between two classes. The accuracy of classification is verified by giving the test sample data as input.

The margin based calculation is only applicable for linear dataset [8]. For non linear SVM classification, Kernel selection can be used to classify the data. Kernel selection is a crucial issue for support vector machines. A kernel introduces nonlinearity into the SVM problem by mapping the input dataset into space ϕ where the data get linearly arranged.

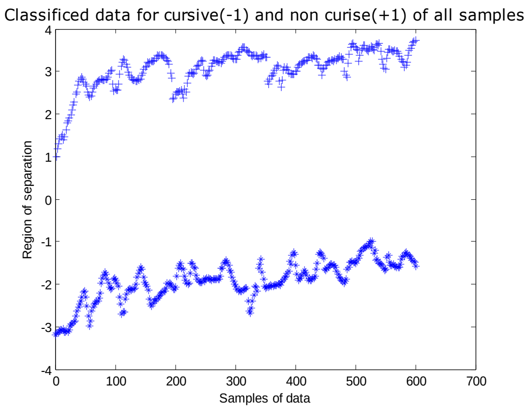

Figure 5. Classified samples in SVM plane

Kernel technique can be approached to get different types of mapping of support vectors such as Linear, Polynomial, RBF, Sigmoid, and Wavelet.

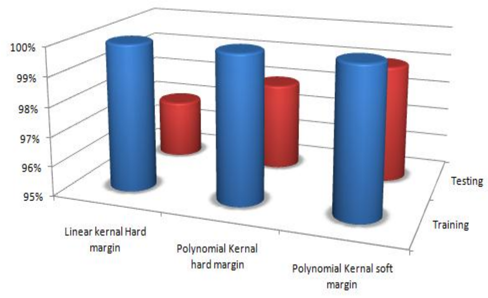

Figure 6. Data classification accuracy using SVM

For the classification of writing styles, SVM kernel technique is approached since the data set retrieved from sensors are distributed non-linearly. Kernel SVM formulation is done using MATLAB program and data sets are simulated using the program. The first two kind of kernel mapping has been approached in this paper. The SVM simulation provided the classification in terms of percentage of training and testing samples. Figure 5 shows that the samples for different styles have been classified accurately. The approach has been executed for different algorithm and the results of test-train accuracy of samples are shown in Fig. 6.

VII. Result and Applications

On analysing writing styles using SVM technique, the results showed an accuracy of 100% in classifying two writing styles. Further it shall be proved that same accuracy can be obtained when the sample subjects improved further. Moreover, it was found that the total force used by different subjects from various nationalities to write in non-cursive style of writing was less than the cursive style. The total force exerted by the three fingers for non-cursive style was found to be in the range of 0 to 7N while that of cursive style was found to be greater than 7N. Although the analysis showed the expected result of thumb exerting the maximum force, the analysis showed an interesting result wherein the force on middle finger is higher rather than the usually expected index finger.

The results obtained using this comparative study shall be one among the other important factors to consider when designing a prosthetic hand [9]. In other words, the design of the sensors at each of the finger tips of the prosthetic hand should satisfy the force analysis computed above so as to give an exact match of the natural human hand. Furthermore, the above analysis can be used to instruct people, who are about to use prosthetic hand, to prefer a non-cursive style of hand writing since the force exerted is less, thereby giving a longer life for the sensors placed at the finger tips as the power consumption will be less for this style of hand writing.

VIII. Conclusion

The comparative study made in the previous section shows the force difference between cursive and non-cursive using MATLAB. The mean value of forces applied on three fingers namely, the thumb, index and middle finger along with the mean value of the total forces, used in the two styles of writing, were found. The concept of SVM was used to classify between the two styles of writing based on the mean value of forces for which, a train and test accuracy of 100% was achieved.

IX. Future Work

The analysis carried out in this paper is limited in terms of language. In other words, English was the preferred language in this analysis which can be extended to other languages as well. Moreover, the analysis can be extended to find the energy spent by an individual in writing. This energy analysis shall be helpful in determining why majority of people tend to chose non-cursive style of writing over cursive style, provided the results coincide with the above conclusion. Further, since the statistics conducted for SAT examination in the year 2006 at USA showed that only 15% of the total 1.5 million students who took the test wrote in cursive, a study on various nationalities with their brain-hand co-ordination can be carried out so as to find the reason for people preferring a non-cursive style of writing.

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