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Mental Health Analysis Using Handwriting by Generating Writing Prompts

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Abstract: Handwritten text is known to mirror an individual's mind and body coordination. Graphology is the study wherein handwriting analysis is used to draw conclusions about a person's psychological status. The proposed methodology focuses on developing a system that can predict the mental health of a person with the aid of machine learning without human intervention. To make this happen, seven handwriting features are considered, these features are: (i) size of letters, (ii) slant of the writing, (iii) baseline, (iv) pen pressure, (v) spacing between letters, (vi) spacing between words and (vii) top margin in a document to predict if the writer has any of the 3 mental illnesses: Stress, Depression and Anxiety. The main objective of this paper is to extract features from handwritten text which will be then normalized, scaled and used to draw conclusions about a person's mental health. Min-max algorithm, KBinsDiscretizer is used for scaling, normalization and discretization of the values obtained. Further, four support vector machines will be used to classify the results derived from the mentioned algorithms. The accuracy achieved by the SVM model over the test dataset is 98.58%. The methodology, datasets, and future scope of M.L in graphology have also been included.

Index Terms **– Graphology, Handwriting Analysis, Mental Health, Machine Learning, SVM classifier.**

I. INTRODUCTION

Several studies conducted have analyzed the psychological and emotional correlation that mental health has with handwriting. Handwriting Analysis/graphology is a practice that has existed since the 1800's [1]. Comprehending a human's mental health state in its entirety is an extremely complex task that integrates several fields of research. Graphology has been used as a tool to comprehend and understand a person better, presently, the use of graphology/handwriting analysis has been noted in in varied sectors like: employee profiling, digital forensics, and personality traits recognition. There has been a sufficient use of this study (graphology) by employers to analyze the behavior of the employees, as handwriting is said to reflect the psyche of a person. Mental health is the level of psychological well-being or is referred to as cognitive, behavioral, and emotional well-being. The WHO predicts that by 2022, roughly 20% of all Indians will be diagnosed with a mental illness in their lifetime. And as per reports from the National Alliance on Mental Illness, [2] only about forty per cent of adults and fifty per cent of youth receive the medical assistance they need.

Though mental illness can hit anyone, there still exists a stigma attached to it, which creates shame and hesitance in seeking aid. With so much existing information on the correlation between handwriting and mental illness, it should not be something to be ashamed about or thought of differently. The awareness, recognition and realization of mental illness has come a long way from how it used to be, but there is always room for improvement. Due to the stigma around mental health, people tend to avoid these conversations, which would just harm them more. Moreover, seeking professional help might seem like an invasion of privacy or might not be economically feasible for a lot of individuals. Hence, to tackle the problems like these, this paper will introduce a way of self-diagnosis, which will then encourage them to get the right kind of help.

The project demonstrates how by taking an input from the user we can generate results and draw conclusions about their mental health. The project contains various segments like: accepting the input from the user, pre-processing the image by using functions from OpenCV and Adobe Photoshop and python, extracting a total of seven features from the image, post-processing of the image which will include scaling, normalization and classifying. The use of Machine Learning algorithms for identifying handwriting patterns and features will be demonstrated in the paper. IAM dataset will be used to train the model, this dataset contains contributions from 657 writers.

II. LITERATURE SURVEY

Many ways to automate graphology have been seen before. But most of these attempts do not demonstrate direct identification but are rather ideas and concepts.

In [3] the personality of an individual is predicted from each character/letter extracted from the handwriting. This project focuses on the personality traits of a person. Features like—size of the stem of particular characters or letters, the round in letters, tall-ness of characters are used as inputs for analysis in this system. GHT, Generalized Hough Transform, a transformation technique is used to identify patterns like size of the stem in letter Y, loops made in the letter O. Each letter is considered separately and analysed to predict the personality traits of the person. This study determines personal features like: talkative, broadminded.

In [4] types of behaviours are classified into 3 categories—positive, negative social behaviour and personal behaviour. This paper demonstrates the use of converting script into zones and carrying on with the analysis. The scope of the proposed work is to study features of individual characters after segmenting the text, converting them into zones. In this paper, it is noted that a person with extreme depression might show signs of tremors in the handwriting and might not have the smoothest handwriting. The paper will focuses on the methods by which a user can control his emotional outbursts.

In [5] where a convolutional neural n/w is used and is presented as a DASS quiz. Which is presented in a question-answer format which is then used for emotional recognition. DASS stands for—Depression, Anxiety and Stress scale. This is a diagnosis derived from a questionnaire which recognizes the emotional state of a person. This questionnaire consists of 42 questions. It is both for adults and adolescents, it is based on the research by research professionals and clinical practitioners. The Depression Scale in the DASS questionnaire assesses dysphoria, hopelessness, devaluation of life, self-deprecation, and lack of interest/involvement, anhedonia, and inertia. The Anxiety Scale assesses autonomic arousal, skeletal muscle effects, situational anxiety, and subjective experience of anxious affect. The Stress Scale is sensitive to levels of chronic non-specific arousal. It assesses difficulty relaxing, nervous arousal, and being easily upset/agitated, irritable/over-reactive and impatient.

In [6] parameters such as baseline, pen pressure and the letter ‘t’ are used as inputs to the Artificial Neural Network which outputs the personality trait of the writer by examining multiple samples using MATLAB. The evaluation of the baseline is done using the polygonalization method and grey-level threshold value is used to evaluate the pen pressure. The height of the t-bar on the stem of the letter‘t’ is calculated using template matching. It determines various personality traits like: Pessimistic, Optimistic, high/moderate/low self-esteem.

In [7] nine features: size, slant of words, word spacing, breaks in handwriting, pen pressure, margin, baseline, loop of ‘e’ and the distance between title(dot) and stem of ‘i’ are considered for developing the handwriting analysis system which achieves an accuracy of 93.77%. These extracted features are then used to predict the behavior of the writer using a n-class classifier where n>1. This system predicts human behavior such as introvert, extrovert, sensitive to atmosphere, risk taker, analytical thinking power, sensitive, dependent/independent, consistent, self-reliant and open minded.

III. METHODOLOGY

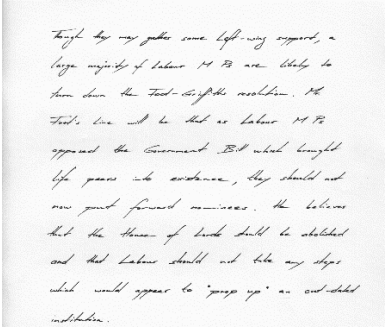
Human intervention might be effective but it can often be inconsistent and not cost-effective. Analyzing all significant characters manually is time consuming and hence automating the analysis will speed up the process, be cost-effective and also give consistent results. The system generates a writing prompt which is handwritten by the user and uploaded. Support Vector Machines will be then used for classification.

3.1 Pre-processing

After the image is uploaded into the system. Pre-processing of the image starts. The handwriting images obtained from the users may contain unwanted noise, printed text and lines. The original images might have a very big resolution by default. The aim of pre-processing is to make the image data suitable for feature extraction by removing unwanted attributes, enhancing the quality, and performing transformations.

3.1.1 Image Resolution and Cropping

Adobe Photoshop will be used to run an action script, a pure python script can also be used for the same, this algorithm will crop the margins and resize all the images to 850p in width and height and will convert the image from other formats into PNG. PNG is preferred over other formats because it’s a lossless format.



3.1.2 Noise Removal

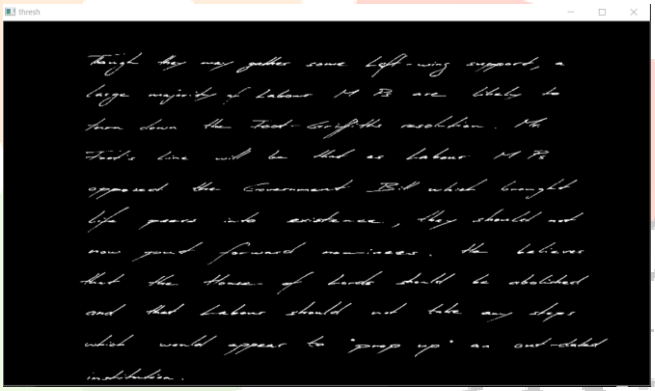
Image noise has to be removed so that extracting features can be seamless. Noise is classified into types like: Salt and Pepper, Gaussian, Gamma. For the removal of these types of noise, bilateral filtering is used, which preserves the edges and then smoothens the image resulting in noise removal.

3.1.3 Grey-scaling and Binarization

Every pixel in an image is made of 3 colors which are Red, Green, and Blue. But for extracting features, binarization and grey-scaling have to be applied. Each pixel is classified into either foreground or background and then each pixel undergoes binarization wherein it is assigned either black color or white color. This is done by using global-inverted thresholding. The operation can be formulated as:

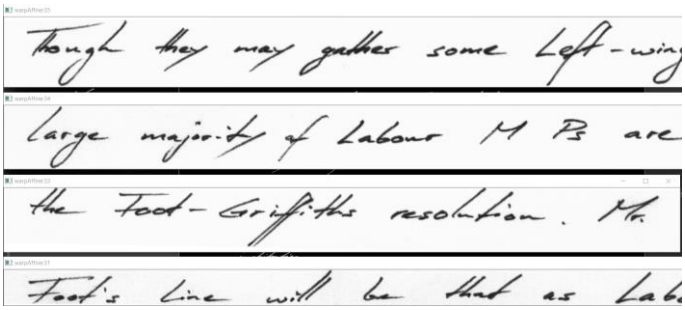
$$\texttt{dst}(x,y) = \begin{cases} 0 & \text{if } \texttt{src}(x,y) > \texttt{thresh} \\ \texttt{maxVal} & \text{otherwise} \end{cases}$$

Here, src(x,y) represents intensity of a particular pixel.



3.1.4 Extracting Lines

After noise is removed and the image is converted to grayscale and inversely binarized, the lines of the handwriting need to be straightened, this is done by using an OpenCV library which contains functions like dilation and warp affine and contouring. After applying these 3 functions to the image the lines of the handwriting are extracted by using horizontal projections.



3.2 Feature Extraction

After the image goes through the multiple stages of image processing namely: sizing and cropping, noise removal and grey-scaling and binarization, it will then be ready for feature extraction. A graphologist might use simple, and complex characteristics to predict the psychological state. Out of those, this study uses seven features, which are: Baseline Angle, Letter Size, Line Spacing, Word Spacing, Top Margin, Pen Pressure, and Slant Angle.

3.2.1 Baseline Angle

According to studies by graphologists, one of the features they look at is the levelness and the steadiness of the handwriting. Hence, 3 types of baseline angles: straight, rising and falling baselines need to be identified.

The pre-processed image was converted into a binary image and dilation was applied so as to extract horizontal segments. Now, minimum area rectangle function is used on the pre-processed image which creates a horizontal straight line with respect to which

the baseline angle is then calculated. A value is generated for every horizontal segment, the average of these angles is then determined as the baseline angle.

3.2.2 Letter Size

While calculating the baseline angle, horizontal segments were extracted from the handwriting. These horizontal projections will be then used in order to calculate the letter size as well. The average width of each the horizontal projection will be considered as the size of the letter. Only the mid-zone of the horizontal projection is used to calculate this value.

3.2.3 Line Spacing

The number of rows whose horizontal projection is zero is counted after removing the top margin. Now the number of rows where the horizontal projection is zero is added to rows where the value is less than the threshold. This value is then divided by the total no. of lines to get a value say‘s’. Value‘s’ is then divided by the letter size, so that the two values are relative.

3.2.4 Word Spacing

While calculating baseline and line spacing, horizontal projections were used. For calculating word spacing, vertical projections are computed. Word spacing is calculated the same way as the line spacing and it is relative to letter size as well. The value returned is the average of the word spacing from each vertical projection.

3.2.5 Top Margin

To compute top margin, the algorithm scans the horizontal projections which were computed while calculating the baseline angle and then calculate the number of horizontal projections whose values is zero till the first non-zero value is encountered. The number of 0 's is the height of the top margin, which is again divided by the letter size so that it is relative to the handwriting size.

3.2.6 Pen-Pressure

An inverted binary threshold is performed where if pixel(x, y) is lower than threshold=100, the new pixel value newpixel(x, y) will be set to 0, else it will be left untouched.
The average value of all the non-zero pixels is taken as the pen pressure. The value is not inverted again (to reverse the effect of step 1) so that higher value would mean higher pen pressure.
When an input image is inverted with the given threshold, pressure points are visible to the naked eye.

3.2.7 Slant Angle

To calculate the slant angle of the handwriting shear transformation is used. For 9 different angles (-45, -30, -15, -5, 0, 5, 15, 30 and 45 degree), a shear transformation is applied and the following histogram is calculated.
$H(m) = h(m)\ \Delta y(m)$
Where,
H(m) is the vertical density (number of foreground pixels per column) in column m
Δy(m) the distance between the highest and lowest pixel in the same column.
If the column m contains a continuous stroke,

H(m)=1,
Otherwise, H(m)[0,1].

For each shear transformed image, the following function is calculated.

$S = \Sigma h(i)^{\wedge} 2$

The angle giving the highest value of S is taken as the slant of the handwriting

3.3 Post-Processing: Scaling and Normalization

This is the last step in the process pipeline. After the features are extracted from the images, seven values are obtained. Extracting these values from an image would give an output which would look like this:

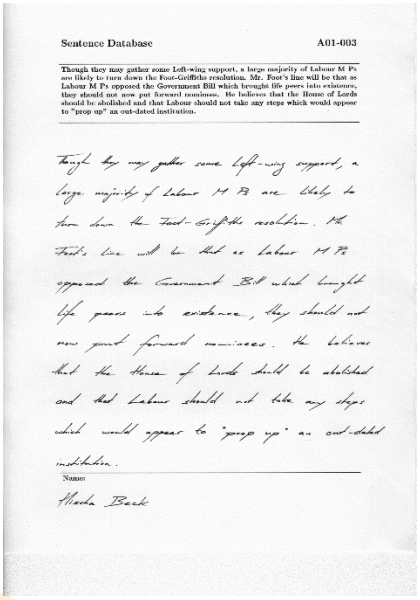
```
(py2) PS C:\Users\DELL\Downloads\uploads\uploads> python myextract.py
Baseline Angle:  -0.21
Top Margin:      2.79
Letter Size:     61.75
Line Spacing:    1.46
Word Spacing:    1.17
Pen Pressure:    176.04
Slant Angle:     45.0
```

These seven values are of the float type. These values are individual, independent values. The range of these values is quite big. Hence, to draw conclusions from these values they need to be scaled and normalized.
Min-max algorithm is used for scaling the values. This gives us a set of continuous values in the range of 0 to 1.
To discretize the values obtained from the min-max algorithm this paper uses KBinsDiscretizer.
To classify the data, SVM (Support vector Machine) classifiers are. Four SVM classifiers will be used to do the same. These SVM classifiers will be used for classifying handwritings into 3 major disorders namely: Anxiety, Stress and Depression and the fourth classifier will be used to classify the normal cases. This will be purely based on prefixed threshold values. The accuracy of these classifiers was calculated using the sklearn library and the accuracies of these four classifiers were found to be 100%, 100%, 98.86% and 95.45% respectively. Hence resulting in an overall accuracy of 98.58%.

IV. DATASETS

EMNIST dataset was previously chosen as it contained samples of different alphabets which were pre-segmented. EMNIST dataset has a balanced set of uppercase and lowercase alphabets and is compatible with the MNIST dataset. However, using this dataset would mean that the machine cannot be used for cursive handwriting and algorithms for segmentation analysis and zonal analysis can only be used. Due to these shortcomings, this EMIST dataset was dropped.

Hence, choosing the IAM dataset containing handwritten samples to train the model proved to be better. This dataset contains samples written in English only. It contains 1539 pages of scanned text, which we use to train our model. A total of 657 writers have contributed to this dataset. The images contain a writing prompt at the starting of the page followed by the handwritten sample. While processing the images during the pre-processing stage, the images are cropped and re-sized the so that only the handwritten text is taken into account. A sample from IAM dataset is illustrated below.



V. APPLICATIONS

Graphology and handwriting analysis has a variety of applications ranging from employee profiling to forensic analysis. By using graphology, we can analyze the mental illnesses of an individual which can be then used for employee profiling. This can also be used by human resources in companies in order to examine stress levels of their employees. As mental health directly affects a person's productivity and efficiency. It can be used clinically by counsellors and psychotherapists alongside other projective personality assessment tools. Often times getting a diagnosis from a professional is not economical and not everyone can afford it. Hence, by using the application they can get an insight into mental health problems and also seek help.

VI. CONCLUSION AND FUTURE SCOPE

In this paper, we have demonstrated how we automated concepts of graphology and trained our model in order to extract features from images and derive conclusive information about a person's mental state. Using seven handwriting features, three illnesses were predicted, them being: depression, anxiety and stress. For normalizing and scaling SVM classifier was trained for each of these illnesses. To optimize the results obtained, the paper demonstrates the usage of libraries like OpenCV, for image processing. Using these libraries helped us to derive and achieve the results much faster. It also improved the accuracy which would've been much more difficult otherwise.

Due course of this research, IAM dataset was used. IAM dataset has a limited set of samples which restricted the training of the model. In the future, acquiring an increased number of samples would help train the machine learning algorithms. Making the algorithms adaptable to handle extreme cases would be another goal that can be looked at in the future. To make this system more accessible to the clients an interactive GUI can be introduced.

VII. ACKNOWLEDGEMENT

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