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A Critical Review and Conclusion

*“When quantifying a job counts is,
what you have got out of it,
more than what people will get out of it”*

8.1 A Critical Review

Everything that is newly invented has its merits and demerits. The assessment of the newly invented thing is, perhaps, the most crucial phase in not just the invention process, but also in the decision of retaining it as useful, or in proposing to bring in modifications to improve the performance, or discarding it as unworthy. But, in fields where robust and/or credible methodologies are already existent, a new approach introduced should not only be entirely assessed, but it should also be thoroughly compared with the existing ones. This gives a clear picture of not only how good the new approach is, but also if it is worthwhile pursuing improvements over the methodology, and also where the approach stands against the state of the art. The newly proposed approach should closely follow the already existing robust ones, and be preferably even better. This is the surest way of bringing in any kind of credibility to

tile approach right In its Inception. The following subsections might be or use in assessing the new approaches that we have taken up in our research work.

As per to the best of our knowledge and efforts, we could not find standard methods for the recognition of Pitman Shorthand notation, or for that matter, the likes of it. This makes it impossible to carry out a comparative study of the approaches that we have introduced with the already existing ones. Instead, we have made an extensive study of the three methods we have used, viz., Hough Transform, Graph-theoretic and Regional Decomposition methods for the recognition of Pitman Shorthand notation. We have compared all the methods with one another, and made an effort to assess the superiority of a particular method, in a particular aspect, over the other methods.

The three proposed algorithms, essentially achieve the same, in that they recognise individual consonants in a Shorthand word. However, each method builds up different methods to recognise the consonants (and ultimately, the word) A comparative study was made over a typical set of phonetic words. The study is depicted in a tabular fashion in Table 8.1. The time taken for recognition of a single Phonetic word is very much less (nearly zero). Hence in all the three methods, every typical Pitman Shorthand word given in the Table 8.1 is allowed to be recognised for 1000 times at a stretch and the average recognition time is tabulated.

The Table 8.1 shows how the methods fare, as far as speed of recognition of particular words is concerned. The times are in terms of millisecond (10⁻³ seconds), and each of the columns specifies the time taken up by each of the approaches to recognise the particular word given in the first column.

The sample set for which the recognition rates are listed, are simple Pitman's shorthand words. The samples selected consist of words made up of only straight strokes, and those with a combination of straight strokes and circular (arc) strokes, and those with strokes that have consonants with loops and hooks. The sample set consists of different consonants with every important feature the notation has.

Once again, we would like to emphasise the point that this research work is basically, an attempt to study the possibility of automation of text-production from Pitman Shorthand. We have limited ourselves to the translation of simple phonetic words to English text.

8.1.1 Hough Transform Method

It is clear from the table that Hough Transform takes up more time than the other methods, on an average-basis. This can be explained by the fact that Hough Transform does a lot more computations (mathematical), than the other methods, before reaching a point when it clearly distinguishes the word.

A lot of time is spent doing the computations required to create the following processes over a phonetic word

- i. Three divisions of the phonetic consonant,
- ii. Hough Accumulator, for each of the three fragments.

The creation of the Hough accumulator is a computation-intensive process, and goes on to prove to be the most expensive part of the approach, as far as time is concerned. But the method fares well, when the consonant it is acting upon is a straight line segment. On the other hand, if the consonant happens to be an arc of a circle, the process requires more time. It is also observed that a straight line with a hook at one of its end, takes up as much time as does an arc of a circle. Probably the most important aspect, that decides the time factor is the fragment size. The bigger the fragment size, the more time the method requires. Usually the fragment size varies because of the nature of the stroke. A curve will have a slightly smaller fragment than a straight line.

8.1.2 Graph-theoretic Method

On an average-basis, it is clear from the table 8.1 that Graph-theoretic method takes up less time compared to the Hough Transform method. This can be explained by the fact that graph-theoretic method does not need any computations compared to Hough Transform method.

This method has two major phases in recognition process

- i. Determining the start-vertex

ii. Recognising the consonant

The major time consuming phase between these two is determining the start-vertex. It takes more time if the first consonant of the word is a straight line with a hook (W and V), a straight line with a loop (H), a 60° line (CH and J), an arc of a circle - left most (TH and *TH*) or an arc of a circle - bottom right (SH and ZH). Because in each of these cases, we get a bi-valent vertex on the left edge of the imaginary rectangle enclosing the word. From this bi-valent vertex, we traverse the word to find the vertex that is not bi-valent and which is nearest to the left edge of the imaginary rectangle. In all other cases, the time taken in determining the start-vertex is minimal.

For the second phase, i.e., recognising the consonant, the only processing done is determining the neighbour, contour traversing in that direction and generating hexa-code for each fragment. The time consumed depends on the length of the stroke, thus, there is no difference between time consumed to recognise a straight line and an arc of a circle.

The major advantages of this method are

- The recognition process does not depend on the length of the stroke.
- The method takes care of slight variation in the writing.

8.1.3 Regional decomposition method

It is clear from table 8.1, that the Regional Decomposition method is the fastest of the three methods. This is because of the fact that this method does not traverse the entire stroke, in order to make the recognition, instead, it concentrates on key locations to extract special features, which prove to be sufficient in order to make a clear-cut recognition. By-passing the traversal proves to be a major time-saver. Another important feature of this method is the in-built decision-tree, that is an integral part of the method. Whenever a key-feature of a stroke is reckoned, the search domain is reduced to characters with that feature. Some computation overhead will be incurred, because of this tree-traversal, but ultimately it is compensated with the saving of time because of not having to traverse the entire stroke.

Another important point is that the recognition rate slightly increases, when the stroke is curved in nature. This is because, the immediate recognition of the nature of the curve

seems impossible in curved structures. To overcome this, the method traverses the stroke around the region of the key-points, to extract more information which will help in the recognition.

8.2 Summary

This research aims at the automation of recognition of Pitman Shorthand notation, and production of its English-text equivalent. This work revolves around the concepts of image processing and pattern recognition, or more specifically, character recognition. We have considered Pitman Shorthand notation as the pattern. We have used Pattern Recognition techniques to recognise the Pitman Shorthand words. This research is in the direction to relieve the stenographer from the mechanical drudgery of decoding and typing the shorthand text. We have employed three-phase method to recognise and reproduce a English text from a phonetic word. The phases are (i) Scanning the pitman text document and preprocessing of the image, (ii) Pattern Recognition algorithms used for recognition purpose, and (iii) Construction of English words from pattern shape descriptors, using a phonetic knowledge-base.

In the preprocessing stage we have defined a four-level [0 - 1/3 - 2/3 - 1] intensity image, in order to discriminate background, reference line, light-stroke and dark-stroke. Modified algorithms are used for word-level separation in a Pitman Shorthand document, which is different from normal text.

Noise-removal method is an indispensable part of the recognition process for two reasons. Firstly, scanned images are very likely to contain a lot of noise, and secondly, the characteristic feature of the notation being very sensitive towards noise, especially those that resemble the ones in the notation's vocabulary (noise in the form of dots and dashes).

The stroke is thinned, in order to reduce the overhead incurred during the recognition process.

The recognition of Pitman Shorthand notation involves identifying the constants and the sequence of consonant segments and connecting vowels in a phonetic word. To achieve this purpose three different Pattern Recognition methods are designed.

1. Hough Transform based algorithm.
2. Graph-theoretic interpretation and contour-traversal based algorithm.
3. Regional decomposition based algorithm.

Hough Transform is a Pattern Recognition technique, which is normally used for identification of linear structures in a binary image. The property of linearity in the Pitman Shorthand notation has been exploited in our attempt to adopt the Hough Transform technique to recognise the primitives of the notation.

Graph-theoretical interpretations of the notation have been extensively used in the design of a very efficient mechanism of character recognition, or more specifically, recognition of Pitman Shorthand notation. A word in the notation resembles a Hamiltonian path, and hence the traversal becomes uni-directional. The traversal of this path yields the 8-directional codes, which when fed into a built-in finite automaton, generates fragment codes (Hexa codes). These fragment codes help in the recognition of the stroke.

We have designed a Regional Decomposition method to recognise the notation at the word-level. This is a modification over Suen's Regional Decomposition method, which was employed for the recognition of English characters and numerals. In this method, we have proposed to enclose a word in a square box, which is divided into 3x3 cells. The intersection points of the stroke with the sides of the cells become the key locations. The features extracted around the key locations, help to carry out the work of recognition. The method is generally, a divide-and-conquer strategy based.

Pitman Shorthand notation is basically a phonetic-based notes-recording medium. The language, in its most primitive form, yields the phonetic composition of a word. What is required of the system is not the phonetic word, but its textual form. To achieve this we have designed a Phonetic Knowledge-base, which functions as an Expert system, to build the textual composition, given the phonetic composition.

We feel that the main aim of the work was to look in to the feasibility or automation of text-production from Pitman Shorthand notation. It was beyond the time frame of this research work to be able to achieve a comprehensive mechanism for English text-production from Pitman Shorthand text. So, we have designed and developed only a minimal recognition mechanism. We hope to see in the future, neither research into the topic leading to devising of a complete recognition model.

8.3 Future Research Avenues

This research work has been an enterprising one, in that it is, to the best of our knowledge, the first attempt towards automation of off-line recognition of Pitman Shorthand words. In our research work we have considered Pitman Shorthand notations of simple English words, at the word-level. As it is a pioneering work in this area, a lot more needs to be done before a comprehensive model for the recognition is built.

In our application of Hough Transform method, we have only used the straight line detection algorithms, by considering the linearity properties, even in the circular strokes. Modified Hough Transform techniques are available to identify circular strokes too, that can be applied for the recognition process.

Hough Transform technique, that we have applied, is at consonant level. The same may be extended to be applied at the word-level. Recognition of dots and dashes using Hough Transform seems to be a possibility, as well. A thorough study in this direction will be helpful.

In the graph-theoretic approach, we have designed a one-level finite automaton. It seems that a multi-level automaton will improve the recognition performance.

The criterion that decides upon the beginning of a consonant in the middle of a word, is the orientation of the stroke, i.e., if there is a drastic change in the flow of the stroke, the method considers it as the beginning of another consonant. A better method for identifying the point of beginning of a consonant needs to be designed.

The application of the graph-theoretic approach might prove to be for more efficient for online recognition. than most other method, because of the ease in the availability of Information regarding the starting point of the stroke (pen-down point), and the dynamics of the stroke flow. The method may be revised for the purpose of online character recognition.

In the first two methods, we have considered that every stroke to be made up of three fragments. Processing the fragments does not depend on each other, hence a degree of parallelism can be acheived in both the methods, by having as many processors working on the three fragments, concurrently.

In the method of regional decomposition we are fixing the number of cells to $(3 \times 3) 9$. A more dynamic regional decomposition method can be designed, where the number of cells solely depend on the stretch and now or the stroke.

The proposed three methods show prospects or applicability in recognition at the sentence-level and also in the recognition of grammalogues and phraseographies.

In brief, our study has been successful in establishing that it is possible to automate the production of text from Pitman Shorthand notes. However, the whole exercise has been with simple phonetic constructs. Therefore, a large volume of research is envisaged in the future, before a perfect reproduction of English text from Pitman Shorthand notes can become possible.

<i>Shorthand Words</i>	<i>English words</i>	<i>Hough transform</i>	<i>Graph theory</i>	<i>Regional decomposition</i>
	bet	5	2.098	1.098
	calm	3.901	1.197	1.648
	tamil	8.681	1.868	3.296
	awoke	5	4.197	1.648
	kid	3.351	1.329	1.098
	hid	5.934	1.909	0.549
	pull	8.021	2.059	1.098
	coal	6.373	0.967	0.549

Table 8.1 : Time consumption by different methods (in milli-seconds)

**List of the Author's Publications
based on this Thesis**

1. P. Nagabhushan, G. Hemantha Kumar, "Automatic Recognition of English words from Pitman Shorthand Notation", accepted for presentation at International Conference held in Italy - 1997, IGS'97 : International Graphonomics Society: Research on Handwriting and Drawing [IAPR].
2. P. Nagabhushan, G. Hemantha Kumar, "Automatic Recognition of Shorthand Notation Using Hough Transform", accepted at International Conference on Cognitive Systems (ICCS'97), held at New Delhi, India, Dec. 1997.
3. P. Nagabhushan, G. Hemantha Kumar, "Hough Transform Based Algorithm for Automatic Recognition of Pitman Shorthand Text", communicated to the Journal of Pattern Recognition Letters.
4. P. Nagabhushan, G. Hemantha Kumar, "Graph-theoretic Interpretation and Contour-traversal Based Algorithm for Automatic Recognition of Pitman Shorthand Text", communicated to the Journal of Image and Vision Computing, U.K.
5. P. Nagabhushan, G. Hemantha Kumar, "Graph-theoretic Interpretation and Contour-traversal Based Algorithm for Automatic Recognition of Pitman Shorthand Notation". has been communicated to International Conference on Image processing (ICIP'98), to be held in Sept. 1998 in Chicago. U.S.A.

BIBLIOGRAPHY

1. P. Ahmed and C. Y. Suen, "Computer Recognition Of Totally Unconstrained Handwritten Zipcodes ", Int. J. Pattern Recognition Artificial Intelligence, Vol. 1, pp.I-15, 1987.
2. Agrawal R. c., R. K. Shevgaonkar and S. C. Sahsrabudhe, "A Fresh Look At The Hough Transform", Pattern Recognition Letters, 17, 1996, pp. 1065-1068.
3. Alfred V. Aho and Jeffrey D. Ullman, "Principles of Compiler Design", Narosa Publishing House, 1985.
4. Amin, A. Kaced, J.Haton and R. Mohr, "Handwritten Arabic Character Recognition by the I.R.A.C. System", in proc. of 5th Int. Conf. Pattern Recognition, 1980, pp. 729-731.
5. Apsey, "Human Factors for Constrained Handprint of OCR", IEEE Trans. Syst., Man Cybern., Vol. SMC-8, Apr. 1978, pp. 292-296.
6. Ballard D. H., "Generalizing the Hough Transform to Detect Arbitrary Shapes", Pattern Recognition, Vol. 13, No.2, 1981, pp. 111-132.
7. Bernstein, "A Method of Recognising Handprinted Characters in Real-time", in L. N. Kanal, Ed., Pattern Recognition, Washington: Thompson, 1968, pp. 109-114.
8. Berthod, "On-line Analysis of Cursive Writing", in C. Y. Suen and R. De Mori, Eds., Computer Analysis and Perception, Vol. 1 Visual Signals, Boca Raton, FL : CRC Press, 1982, pp. 55-81.
9. Biswas K. K. and Shoma Chaterjee, "Feature-based recognition of Hindi Characters", Proc. of Indian Conf. on Pattern Recognition, Image Processing and Computer Vision, Kharagpur, 1995, pp. 182-187.
10. Blesser, R. Shill man, T. Kuklinski, C. Cox, M. Eden and J. Ventura, "A Theoretical Approach for Character Recognition Based on Phenomenological Attributes", in Proc. 1st Int. Joint Conf. Pattern Recognition, Oct. 1973, pp. 33-40.
11. Bonner, "Segmentation Method and Appratus", U. S. Patent 3,344,399, Sept. 1967.
12. Bozinovic and Sargur N. Shrihari, "A string correction algorithm for cursive script recognition", IEEE Trans. Pattern Anal. Machine Intelligence, vol. P AMI-4, Nov. 1982, pp.655-663.

13. Bozinovic and Sargur N.Srihari, "Off-line Cursive Script Word recognition", IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. **II**, No.1, (1989).
14. Chang and D. H. Lo, "An Experimental System for the Recognition of Handwritten Chinese Characters", in Proc. 1st Int. Symp. Comput. and Chinese Input-Output Syst., 1973, pp. 257-267.
15. Chen, G. Lorette and M. Gaudarie, "Hierarchical Primitives Matching: A Structural Method for Cursive Script Recognition", in Proc. 4th Scandinavian Conf. Image Anal., June 1995, pp. 59-65.
16. Cheng-Huang Tung and Hsi-Jian Lee, "Increasing Character Recognition Accuracy By Detection and Correction Of Erroneously Identified Characters", Elsevier Science Ltd, Pattern Recognition Society, 1994.
17. Christine Nadal and Ching Y. Suen, "Applying Human Knowledge to improve Machine Recognition of Confusing Handwritten Numerals", Pattern Recognition, Vol 26, No.3, 1993.
18. Chun-Ta Ho and Ling-Hwei Cheng, "A High-Speed Algorithm for Line Detection", Pattern Recognition Letters, 17, 1996, pp. 467-473.
19. Crane and R. E. Savoie, "Handwriting System", U. S. Patent 3930229, Dec. 1975.
20. Davis and I. Lyall, "Recognition of Handwritten Characters A Review", Image Vision Comput., pp. 208-218, Nov. 1986.
21. Deo N., "Graph Theory with Applications to Engineering and Computer Science", Prentice Hall of India, 1989.
22. De Luca and Gisotti, "Printed Character Pre-classification based on word structure", Pattern Recognition letters, January 1990.
23. Donahey, "Character Recognition System and Method", U. S. Patent 3 996 557, Dec. 1976.
24. Duda and P. E. Hart, "Pattern Classification and Scene Analysis", New York: John Wiley and Sons, 1973.
25. Duda and P. E. Hart, "Use of the Hough Transform to Detect Lines and Curves in Pictures", comm. ACM 15 (1) 11-15, 1972.

26. Eden and M. Halle, "The Characterization of Cursive Writing", in C. Cherry Ed., Information Theory, London, England: Butterworths, \96\, pp. 287-299.
27. Enrich, "A Contextual Post-processor for Cursive script recognition - summary" in proc. 1st Int. Joint Conf Pattern recognition, Oct 1973, pp. 169-171.
28. Enrich and K. J. Koehler, "Experiments in the Contextual Recognition of Cursive script", IEEE Trans. Comput, vol. C-24, Feb. 1975, pp. 182-194.
29. Fang. "Word-level recognition of Cursive script". IEEE Trans. Comput. vol. (-28. Feb. 1979, pp. 172-175.
30. Fowler H. W. and Fowler F. G.. "The Concise Oxford Dictionary". Oxford University Press 1987.
31. Fox, J.Kin and C.C Tappert, "Segmenter For Known number of characters", IBM Tech. Disclosure Bull., vol.27, Dec. 1984, pp. 3691-3693.
32. Frishkopf, "Automatic recognition of handwriting", U.S. Patent 3,133,266, May 1964.
33. Fujimoto, S. Kadota, S. Hayashi, M. Yamamoto, S. Yajima and M. Yasuda, "Recognition of Handprinted Characters by Nonlinear Elastic Matching", in Proc. 3 Regional decomposition Int. Joint Conf. Pattern Recognition, Nov. 1976, pp. 113-118.
34. George Saon, Abdel Belaid and Yhan Gong, Off-line Handwriting Recognition by Statistical Correlation, I.A.P.R Workshop on Machine Vision Applications, Kawasaki 1994.
35. Gonzalez c., "Digital Image Processing", Addison-Wesley Publishing Co., 1993.
36. Gotcho V. Gotchev, "Computer Linguistic Analysis of Line Drawings", Pattern Recognition, Vol 17, No.4, Pattern Recognition Society, 1984.
37. Han and Fan, "Skeleton Generation of Engineering Drawings via Contour Matching", Pattern Recognition, vol. 27, No.2, 1994.
38. Harmon, "Automatic Reading of Cursive script", in G. L. Fischer Jr., D. K Pollock, B. Raddack, and M. E. Stevans, Ed., Optical Character Recognition. Washington, DC: Spartan, 1962, pp. 151-152(A).
39. Herbst and 1 H. Morrissey, "Segmentation Mechanism for Cursive Script Character Recognition Systems", Patent 4,024,500, May 1997.

40. Higgins and R. Whit row, "On-line cursive script recognition", in Proc. Interact'84, 1st IFIP Conf. Human-Comput. Interaction, Sept. 1984, pp. 140-144.
41. Highleyman, "Data for Character Recognition Studies", IEEE Trans. Electron. Comput., Vol. EC-12, pp. 135-136, Apr. 1963.
42. Hough, P. V. C. (1962), "Method and Means for Recognizing Complex patterns", U.S. Patent 3, 069, 654.
43. Hsi-Jian Lee and Bin Chen, "Recognition of handwritten Chinese Characters via Short Line Segments", Pattern Recognition, Vol. 25, No.5, pp. 543-552, 1992.
44. Huang and M. L. Chung, "Seperating Similar Complex Chinese Characters by Walsh Transform", Pattern Recognition 20, 425-428 (1987).
45. Hull and S. N. Shrihari, "A computational approach to word shape recognition: Hypothesis generation and testing", in proc. IEEE Conf. Comput. Vision Pattern Recognition, June 1986, pp. 156-161.
46. Illingworth and J. Kittler (1988) "A Survey of the Hough Transform", Computer Vision, Graphics and Image Processing, 44, pp. 87-116.
47. Ishii. "Stroke order free online handwritten Kanji character recognition method by means of stroke representation points," Trans. Inst. Electron. Commun. Eng. Japan, 1986, pp. 1069- 1 072.
48. Isaac Pitman, "Pitman Shorthand Instructor and Key", Wheeler Publishing, 1975.
49. Jack Sklansky, "On the Hough Technique for curve detection", Transactions on computers, vol. c-27, NO.1 0, Oct. 1978.
50. Jain and Dubes, "Algorithms for Clustering data", Prentice Hall Publication, 1988.
51. Jairo Rocha and Theo Pavlidas, "A Shape Analysis Model with Applications to a Character Recognition System", IFEF. Translations on Pattern Analysis and Machine Intelligence Vol 16, No.4, April 1994.
52. Jean-Paul Tremblay, Paul G. Sorenson, "An Introduction to Data Structures with Applications", Second Edition, McGraw-Hill International Editions, 1984.
53. John Princen, John Illingworth and Josef Kittler, "A hierarchical approach to line extraction based on the Hough Transform", Computer Vision, Graphics and Image Processing, 52, 1990, pp. 57-77.

54. John E. Hopcroft and Jeffery D. Ullman, "Introduction to Automata theory, Languages, and Computation", Narosa Publishing House, 1987.
55. Joon H. Itan, Laszlo T. Koczy, Timothy Poston, "Fuzzy Hough Translbnn", Pattern Recognition Letters, 15, 1994, pp. 649-658.
56. Ju-Wei Chen, Suh Yin Lee, "On-line Chinese Character Recognition via a representation of Spatial Relationships between Strokes", World Scientific Publishing Co Pte Ltd., 1995.
57. Kah Bin Lim, Kai Xin, Geok Soon Hong, "Detection and estimation of circular arc segments", Pattern Recognition-Letters, 16, 1995.
58. F.Kimura and M.Shridhar, "Handwritten Numerical Recognition Based on Multiple Algorithms", Pattern Recognition, Vol.24, No.10, 1991.
59. Konstantin Y.Kupeev, Haim J. Wolfson, "A New Method of Estimating Shape Similarity", Pattern Recognition Letters, 17, 1996, pp. 873-887.
60. Lamarche and R. Plamondon, "Segmentation and feautre extraction of handwritten signature patterns", in Proc. 7th Int. Conf. Pattern Recognition, 1984, pp. 756-759.
61. Lambert Schomaker, "Using stroke- or character-based self-organizing maps in the recognition of on-line connected cursive-script", Pattern Recognition, Vol. 26, No.3, 1993, pp. 443-450.
62. Leedham and A. C. Downton, "Automatic Recognition and Transcription Pitman's handwritten shorthand -An approach to shortforms", Pattern recognition, Vol. 20,1987, pp. 341-348.
63. Leedham, A. C. Downton, C. P. Brooks and A. I. Newell, "On-line acquisition of Pitman's handwritten shorthand as a means of rapid data entry", in Proc. Interact'84, 1st IFIP Conf. Human Comput. Interaction, Sept. 1985, pp. 86-91.
64. Leedham and A. C. Downton, "On-line recognition of Pitman's handwritten shorthand", 7th Int. Conf. on Pattern Recognition, Montreal 1984.
65. Leedham, "Automatic Recognition and transcription of Pitman's handwritten Shorthand", Computer Processing of Handwriting, R. Plamondon and C. G. Leedham. Eds, World Scientific, Singapore 1990.
66. Lettera, M. Maier, L. Masera and M. I. Pareschi, "Handwritten Documents Recognition with Dictionary Information Support", CSEL T Tech. Rep. (Italy), Vo\ 13, 1985,

pp. 419-422.

67. Lettera, L Masera, C. Paoli, and R. Porinelli, "Use of Dictionary in Conjunction with a Handwritten Texts Recognizer", in Proc. 8th, Int. Conf. Pattern Recognition, Oct. 1986, pp.699-701.
68. LL r. Y. Suen and J. Guo , "A Regional Decomposition Method for Recognising Handprinted Characters", IEEE Transactions on Systems, Man and Cybernetics, Vol. 25, No.6, 1995.
69. Lim, H. H. Teh, H. C. Lui, P. Z. Wang, "Stochastic Topology with Elastic Matching for Off-line Handwritten Character Recognition", Pattern recognition Letters, 17, 1996, pp.149-154.
70. Mantas, "An Overview of Character Recognition Methodologies", Pattern Recognition, 1986, pp. 425-430.
71. Mark S. Sobkow, Paul Pospisil and Yee-Hong Yang, "A fast two dimensional line clipping algorithm via line encoding", Comput. & Graphics, Vo\ 11, No.4, 1987, pp.459-467.
72. Masaharu Wada, "Proposal for fully automated mail processing system *for* the 21 st century". Pattern Recognition Letters, 14, 1993.
73. Michel Gilloux, "Research into the new generation of character and mailing address recognition systems at the French Post Office Research Center", Pattern Recognition Letters, 14, 1993.
74. Minsoo Suk and Som-Myoung Chung, "New Image segmentation techniques", Pattern Recognition Letters, 1983.
75. Mori, K. Yamamoto and M. Yasuda, "Research on Machine Recognition of Handprinted Characters", IEEE Trans. Pattern Ana\ Machine Intell., Vo\ P AMI-6, pp. 386-405, July 1984.
76. Morishita, M. Ooura and Y. Ishii, "A Kanji Recognition Method which Detects Writing Errors", Comput. Processing of Chinese and Oriental Languages, Vol. 3, Mar. 1988, pp.351-365.
77. Nagabhushan P., "An efficient method for classifying Remotely sensed data", Ph.D Thesis - University of Mysore, 1988.
78. Nagabhushan P and G. Hemanth Kumar, "Automatic Recognition of English Words from Pitman Shorthand Notation", IIGS'97] International Graphonomics Society, Italy:

79. Nagabhushan P. and G. Hemant Kumar, "Automatic Recognition of Pitman Shorthand Notation using Hough Transform", ICCS'97 International Conference on Cognitive Systems, New Delhi, Dec. 1997.
80. Nair and C. G. Leedham, "Evaluation of Dynamic Programming Algorithms for the Recognition of Shortforms in Pitman's Shorthand", Pattern Recognition Letters 13, 1992.
81. Nirajan Mayya and V. T. Rajan, "An Efficient Shape Representation Scheme using Voronoi Skeletons", Pattern Recognition Letters, 16, 1995, pp. 147-160.
82. Noboru Babaguchi and Tsunehrio Aibara, "Curvedness of a line picture", Pattern Recognition Vol20, No.3, 1987, pp. 273-280.
83. Pal U. and B. B. Chaudhari, "Printed Devnagari script OCR system", Vivek, 10, 1997, pp. 12-24.
84. Pavlidis and C. J. Wan Wyk, "An Automatic Beautifier for Drawings and Illustrations", ACM Comput. Graphics, Vol. 19, pp. 225-234, July 1985.
85. Peyman Milanfar, "On the Hough transform of a polygon", Pattern Recognition Letters, 17, 1996, pp. 209-210.
86. Pui-Kin Ser, Wan-Chi Siu, "Memory compression for straight line recognition using the Hough Transform", Pattern Recognition Letters, 16, 1995, pp. 133-145.
87. Robert W. Holland, "Principles of Teaching Applied to Pitman's Shorthand", Sir Isaac Pitman and Sons, Ltd, Fourth Edition 1952.
88. Rosenfeld, "Arcs and Curves in Digital Pictures", J. ACM 20 (1), 1973, pp. 81-87.
89. Rosenfeld (1974), "Digital Straight Line Segments", IEEE Trans. Comput. 23(12), pp. 1264-1269.
90. Sargur N. Srihari, "Recognition of handwritten and machine printed text for postal address interpretation", Pattern Recognition Letters, 14, 1993, pp. 291-302.
91. Shillman, C. Cox, T. Kuklinski, J. Ventura, M. Eden, and B. Blesser, "A biography in character recognition : techniques for describing characters ", Visible Language, vol. 8, 1974, pp. 151-156.

92. Soo-chang Pci and Ji-Hwei Il00ng, "Circular me detection based on Hough Transform", Pattern Recognition Letters, 16,1995, pp. 615-625.
93. Subba Reddy, "Neural network and Knowledge-based system for conflict resolution: A new approach", Ph.D Thesis - University of My sore, 1997.
94. Suen. "Character Recognition by Computer and Applications". Handbook of pattern Recognition and Image Processing, T. Y. Young and K. S. Fu, eds., Academic Press, Orlando, Florida (1986), pp. 569-586.
95. Suen, "Distinctive Features in Automatic Recognition of Handprinted Characters", Signal Process., 4, 1982, pp. 193-207.
96. Suen, M. Berthod and S. Mori, "Automatic Recognition of Hand printed characters-The state of the art," Proc. IEEE,vol. 68, Apr. 1980, pp. 469-487.
97. Suen, J. Guo and Z. C. Li, "Analysis and Recognition of Alphanumeric Handprints by Parts", IEEE Transactions on systems, Man and Cybernetics, Vol 24, No.4, April 1994.
98. Suen and R. J. Shillman , "Low error rate optical character recognition of unconstrained handprinted letters based on a model of human perception", IEEE Trans. Syst., Man, Cybern., vol. SMC7, June 1977, pp. 491-495.
99. Suen, R. Shinghal and C. C. Kwan, "Dispersion factor, A quantitative measurement of the quality of hand printed characters", in Proc. SMC Conf., 1977, pp. 681-685.
100. Swamy M. N. S. and Tulsiraman K., "Graph Theory and Application to Network", New York Wiley Publications, 1981.
101. Tokahiko Kawatani and Nobuo Miyamoto, "Verification of Personal Handwriting Characteristics for Numerals and its Application to Recognition", Pattern Recognition Letters. 14, 1993, pp. 335-343.
102. Tappert, "Cursive Script Recognition by Elastic Matching", IBM J. Res. Develop., vol. 26, Nov. 1982, pp. 765-771.
103. Tappert, C. Y. Suen and T. Wakahara, "On-line handwriting recognition -A survey", in Proc. 9th Int. Conf. Pattern Recognition, Nov. 1988, pp. 1123-1132.
104. Tappert, C. Y. Suen and T. Wakahara, "The State of the Art in On-line Handwriting Recognition", IEEE Trans., PAMI 12 Aug. 1990.

105. Teulings and A. J. W. M. Thomassen, "Computer-aided analysis of handwriting movements", *Visible Language*, vol. 13, () 979, pp. 2) 8-23).
106. Wakahara, "On-line Cursive Script Recognition Using Local A1 line Transformation", in *proc. 9th Int. Conf. Pattern Recognition*, Nov. 1988, pp. 1133-1137.
107. Webster' s, *Ninth Collegiate Dictionary*. Merriam-Webster Inc . Springfield Massachusetts, U. S. A.,) 990
108. Wen Tsuan Chen and Rzern-ru Chou, "Heirarchical Deformation Model for On-line Script recognition", *Pattern Recognition Letters*, 1994.
109. Yossi Gofman, "Outline of a Set of Points", *Pattern Recognition Letters*, 14, 1993, pp. 31-38.
110. Yamamoto and A. Rosenfeld, "Recognition of Hand printed Kanji Characters by a Relaxation Method", *Proc. 6th Int. Joint conf. on Pattern Recognition.*, 1982, pp. 395-398.
111. Yizheng Qiao and Graham Leedham "Segmentation and Recognition of Handwritten Pitman Shorthand Outlines, *Pattern Recognition*, Vol. 26, No.3, 1993.
112. Young and K. S. Fu, "Character Recognition by Computer and Applications", Eds., *Handbook of Pattern Recognition and Image Processing*. Orlando, FL: Academic, 1986, pp. 569-586.
113. Yokinobu Tokunaga. "History and current State of Postal Mechanization in Japan", *Pattern Recognition Letters*. 14. 1993, pp. 277-280.
114. Zahn C. T., "Graph theoretical methods for detecting and describing gestalt clusters", *IEEE Trans. Compo C-20*, Jan. 1971.
115. Zhou R. W., C. Quek and G. S. Ng, "A novel Single-pass Thinning Algorithm and an Effective Set of Performance Criteria", *Pattern Recognition Letters*, 16, 1995, pp. 1267-1275.

APPENDIX

Some simple Pitman Shorthand words and their English equivalents

<i>Shorthand words</i>	<i>English words</i>	<i>Shorthand words</i>	<i>English words</i>
	kid		cheap
	bet		leak
	calm		giddy
	coal		hid
	pull		awoke
	fade		arrear
	gull		lunch
	dumb		tamil
	berry		fathom

Some word in Pitman Shorthand notation with their inflexions

<i>Shorthand words</i>	<i>English equivalent</i>	<i>Shorthand words</i>	<i>English equivalent</i>
	kill		killer
	cash		cashier
	name		namely
	pair		repair
	book		bookish
	fair		fairly
	follow		following
	hang		hanging