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Original Research Article

Examination of sequence of strokes by optical method

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ABSTRACT

The sequence in which the writing strokes have been executed on a paper is known as sequence of strokes. Examining the sequence of strokes can help in determining the relative age of ink which is required in various cases related to document examination including examination of wills, cheques, statements, receipts, agreements etc. The current study is focused on examining the sequence of strokes executed with a ball point pen. Video Spectral Comparator 8000 (VSC8000) has been used for the current examination. The test samples and the actual questioned documents were examined under VSC8000. It was observed that depending on the pressure through which the strokes have been executed, identification of sequence of two or more intersecting writing strokes was possible.

1. Introduction

Identification of age of ink is a tough task for a questioned document examiner in the current era. Although determining the exact or absolute age of ink is still a challenging task for a questioned document examiner. A forensic questioned document examiner is able to express opinion on the relative age of ink and paper. Ink examination is used in determination of forgery as well as helps in determining of relative age of ink.[1,2] The relative age of ink can be examined by observing/ examining the sequence of strokes at the point where two or more writing strokes crosses over each other. On the basis of instrument/ pen used to execute the strokes that are crossing over each other or intersecting each other, the intersections may be classified into two groups. The first group is known as homogeneous intersection which means crossing or intersection of two or more strokes that have been executed by the same writing instrument or with two or more instruments of the same type. In this group either same pen can be used to execute two or more intersecting strokes or two or more pens having same ink can also be used. The second group is known as heterogeneous intersections in which two or more crossing/ intersecting strokes have been executed with different writing instruments or same instrument with different inks for example the ink with different shades can be used. Apart from different shades of ink, intersecting of rubber seal impression over pen stroke or vice versa, intersection of ink/ pen stroke over printed matter, intersection of ink strokes/ pen strokes over type written matter, intersection of ink/ pen stroke over pencil stroke or vice versa are also examples of heterogeneous intersections. Examination of sequence of stroke is an attempt done by the forensic document examiner to find out which of the two or more crossing stokes of handwriting executed on a document first and which was executed thereafter. Some research studies have explained more than 30 sequencing techniques involving 144 common types of intersecting media.[3] The techniques used for examination of sequence of two or more intersecting strokes can be classified into two groups i.e the destructive techniques

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and the non destructive techniques. The technique in which the sample may get destroyed or deformed during the process of either examination or pre examination i.e. sample preparation is known as destructive technique. The major reason behind this limitation in the field of questioned document is the limitation in use of analytical techniques preferred as non-destructive techniques[4,5] Examples of destructive technique used for examination of sequence of stroke may include application of certain chemicals which may be required for sample preparation i.e. the chemicals required for pre lifting of the sample. Lifting process done to lift the sample from the document may also destroy sample. Some chemicals used during examination process may also get reacted with the sample and can destroy or deform the sample. The greatest demerit of destructive technique especially in the field of forensic examination or in the examination of a criminal case is the loss of case exhibit that may be required for further proceedings of the case. The second type of technique used for examination of sequence of stroke is known as the non destructive technique. This technique is highly used in the forensic document examination in criminal cases as the case exhibit or the sample remains unaffected/ intact which may be used/ preserved for further investigation of cases. This type of examination includes physical examination of the sample, examination by magnifying glass, microscopic examination including optical microscopes and scanning electron microscope, the photographic technique and micro-spectrophotometry are also being used. The physical and optical analysis is generally performed as a non destructive technique for determining the age of ink which can be done by using the instrument i.e. hyper spectrum; Docucenter expert; advanced video spectral comparator of various range. Forensic document examiners have also been using Raman Spectroscopy for ink examination. The forensic document examiner analyses the frequency of occurring incident of handwriting characteristics as well as sequence of stroke in order to evaluate the accurate scientific data in questioned documents and standard documents.[6–8] There are so many cases we receive in Central Forensic Science Laboratory (CFSL), Central Bureau of Investigation (CBI), New Delhi where age of ink is required to be determined for proving the authenticity of the document such as wills, cheques, statements, receipts, agreements, promissory notes etc. Determination of sequence of stroke becomes more crucial when the executor of the document is unavailable like in case of death of executor. In CFSL (CBI), New Delhi video spectral comparator-8000 (VSC8000) is available and has been used during the current study for examination and analysis for the relative age of homogeneous ink by examining the sequence of strokes of various experimental samples and the actual questioned document. The examination was performed on experimental samples and actual questioned document under various magnifications and using different light sources/ filters and examination by 3D imaging technique. The examination results reveal that sequence of homogeneous strokes where two or more strokes are crossing over each other can be identified using VSC8000 and is a helpful instrument in solving various criminal cases related to document examination.

On literature reviewed on various techniques for determining the sequence of handwriting strokes on documents was done prior to examination on VSC8000 in order to assess the factors for examination that advance or limit each technique and to offer another independent validation of the many sequence-of-stroke methodologies developed and used in forensic document examinations.

2. Materials and Methods

2.1. Technique used

Video Spectral Comparator8000 (VSC8000) is an advanced computerised instrument with an attached monitor which has been used worldwide for questioned document examination, apart from that, it can also be used in other field such as fingerprints etc. With the help of VSC8000 we can examine questioned documents at various magnifications. We can use different light sources ranging from ultraviolet (UV) to Infrared (IR). Various ranges of filters can also be used. Document under examination in VSC8000 can be seen on the wide screen attached to it. VSC8000 has got one more advanced technique i.e. 3D imaging of document. The 3-Dimensional imaging feature for the VSC8000 enables document examiners to derive a 3D model of a documents surface topography in order to better analyse security features, pen-tip strokes and other impressions in paper. Making use of the camera and illumination options already present within the VSC8000, the new 3D imaging mode will be of interest to all professional document examiners but will have particular relevance to those involved in the inspection of signatures and handwriting, particularly in cases of proof of provenance and ownership dispute. Intersecting Lines 3D imaging may be used to determine the sequence in which the lines or marks were added to a document. Here, the first line to be added is broken by a second line, which remains intanct. All the samples were initially examined under various magnifications to study the sequence of execution of strokes and then 3D examination of the samples was conducted.

2.2. Experimental test samples

Total seven samples including the actual questioned document were obtained. Six number of homogenous test samples were procured from different persons which were executed with ball point pens on A4 size sheet where two or more writing strokes were crossing over each other

and actual questioned document which was also executed with the ball point pen was obtained which also contained homogenous crossing of two or more strokes over each other at different points of sample. The samples have been marked from sample 1 to sample 7.

The experimental examinations for all the test samples were carried out with the application of various light source arrangement as well as 3D-image technique of VSC8000. The result obtained by the examination process is detailed with the figures which have been marked from 'Figures 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41 and 42.

2.3. Sample '1' examination of sample under various magnifications

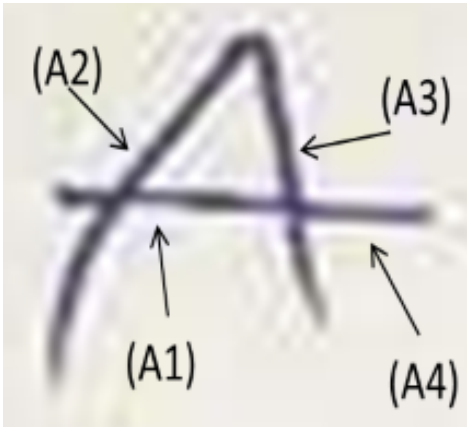


Fig. 1: examination of sample 1 at2X magnification

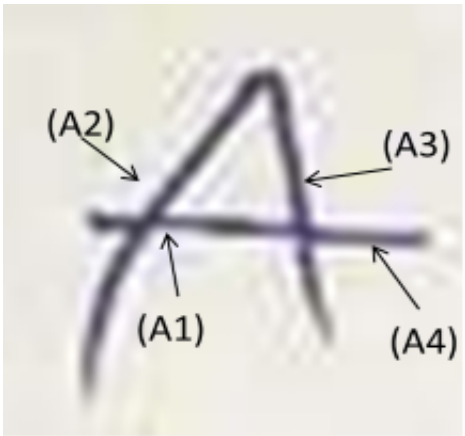


Fig. 2: examination of sample 1 at 4X magnification

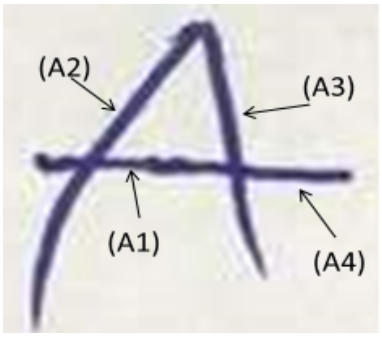


Fig. 3: examination of sample 1 at8X magnification

2.4. 3D Examination of sample at various angles

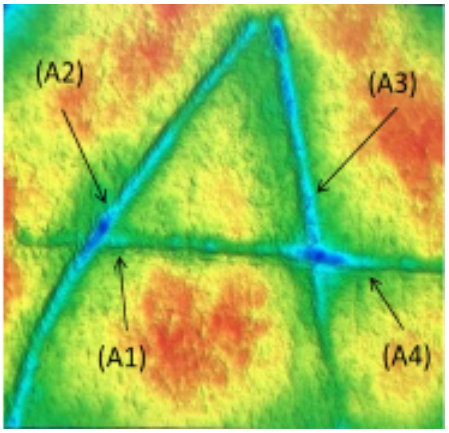


Fig. 4: 3D examination of sample 1

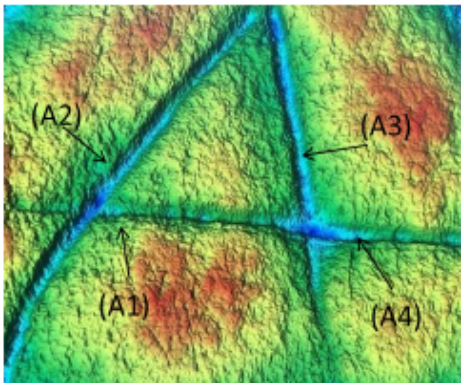


Fig. 5: 3D examination of sample 1

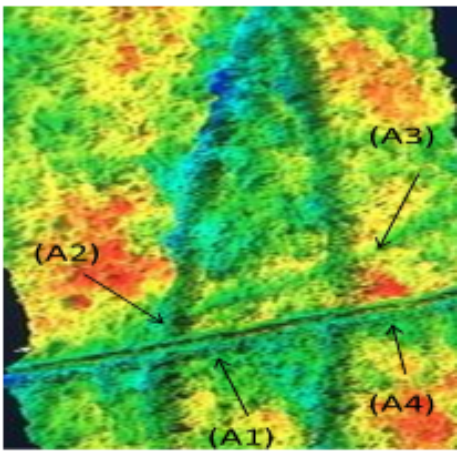


Fig. 6: 3D examination of sample 1

2.5. Sample '2' examination of sample under various magnifications

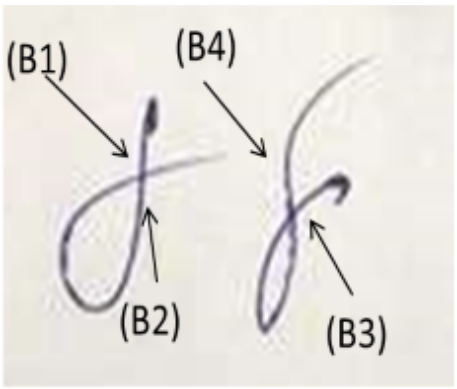


Fig. 7: examination of sample 2 at2X magnification

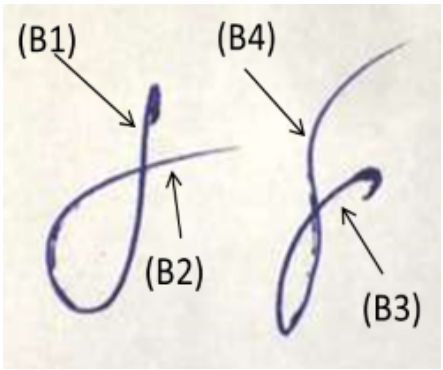


Fig. 8: examination of sample 2 at4X magnification

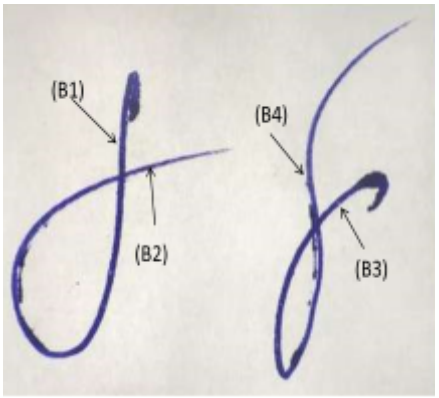


Fig. 9: Examination of sample 2 at8X magnification

2.6. 3D examination of sample at various angles

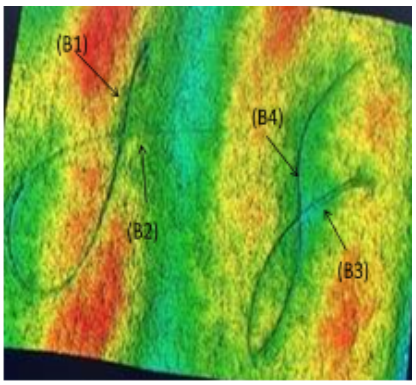


Fig. 10: 3D examination of sample 2

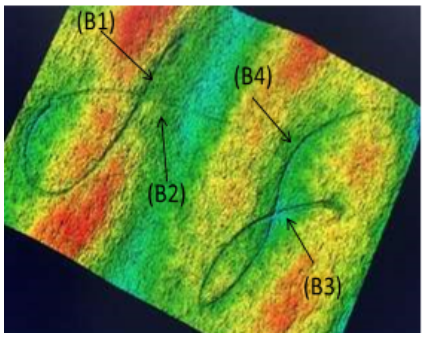


Fig. 11: 3D examination of sample 2

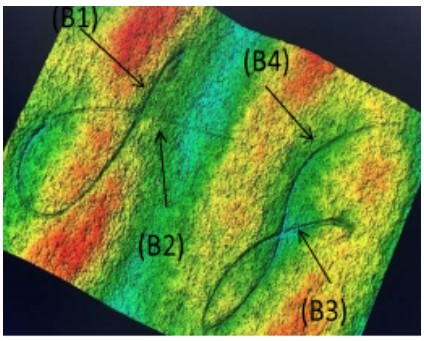


Fig. 12: 3D examination of sample 2

2.7. Sample '3' examination of sample under various magnifications

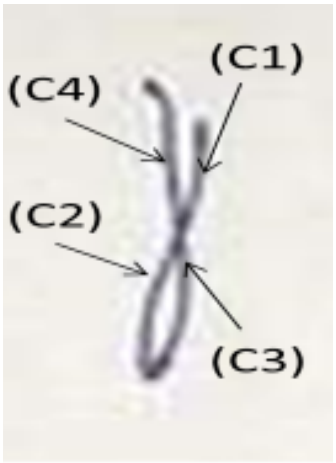


Fig. 13: examination of sample 3 at2X magnification

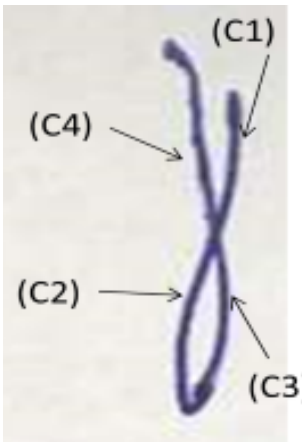


Fig. 14: examination of sample 3 at 4X magnification

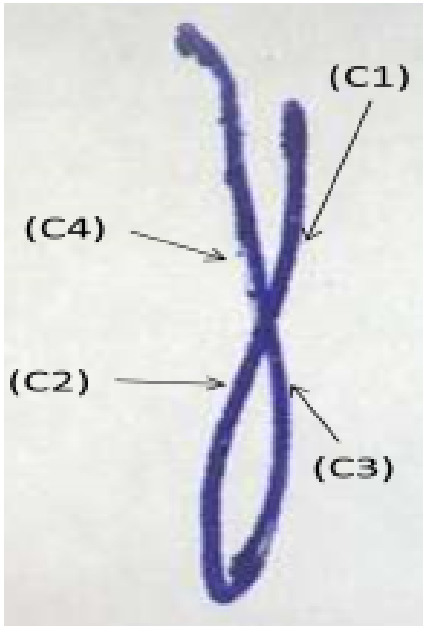


Fig. 15: examination of sample 3 at8X magnification

2.8. 3D examination of samples at various angles

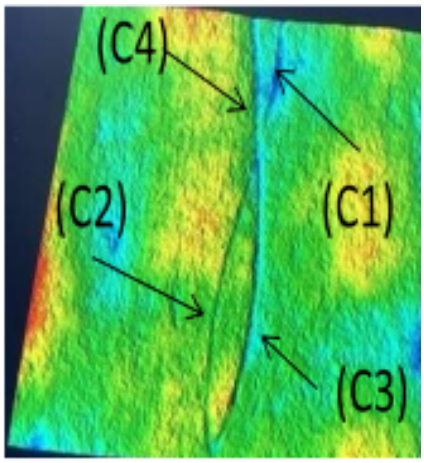


Fig. 16: 3D examination of sample 3

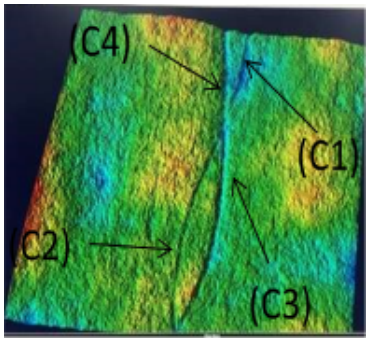


Fig. 17: 3D examination of sample 3

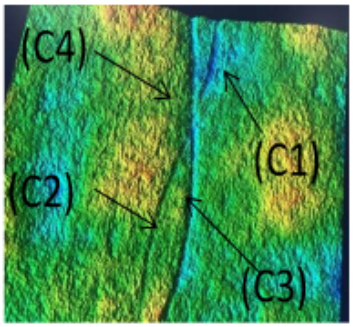


Fig. 18: 3D examination of sample 3

2.9. Sample '4' examination of sample under various magnifications

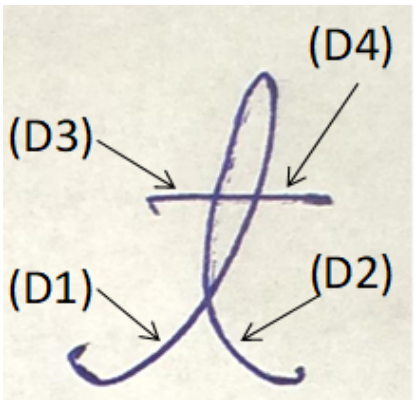


Fig. 19: examination of sample 4 at 2X magnification

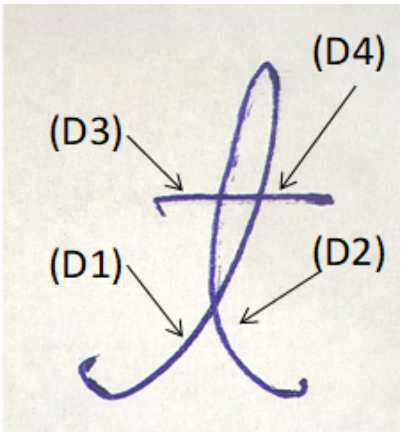


Fig. 20: Examination of sample 4 at4X magnification

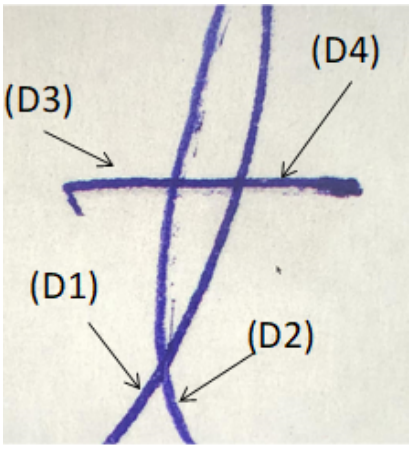


Fig. 21: examination of sample 4 at 8X magnification

2.10. 3D examination of sample at various angles

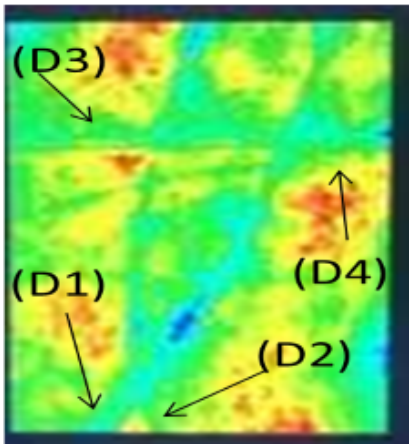


Fig. 22: 3D examination of sample 4

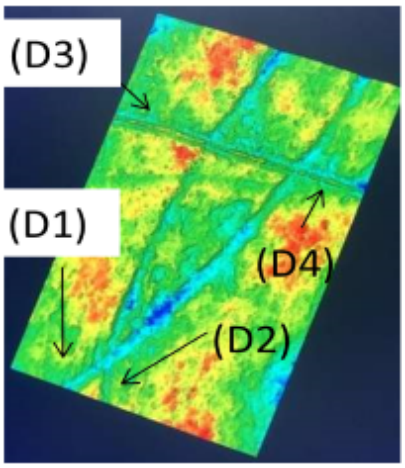


Fig. 23: 3D examination of sample 4

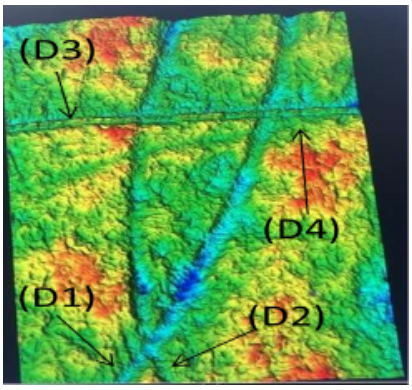


Fig. 24: 3D examination of sample 4

2.11. Sample '5' examination of sample under various magnifications

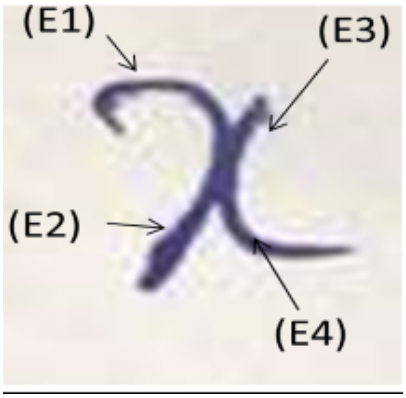


Fig. 25: examination of sample 5 at2X magnification

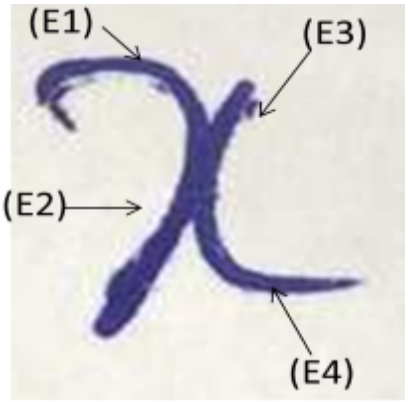


Fig. 26: examination of sample 5 at4X magnification

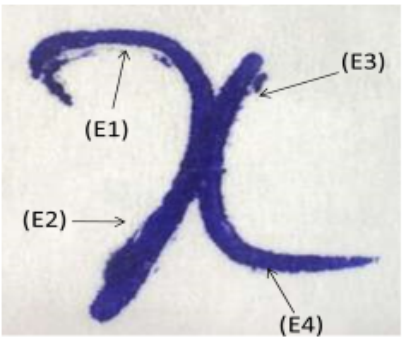


Fig. 27: Examination of sample 5 at8X magnification

2.12. 3D examination of sample at various angles

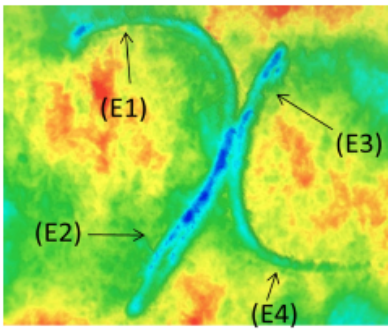


Fig. 28: 3D examination of sample 5

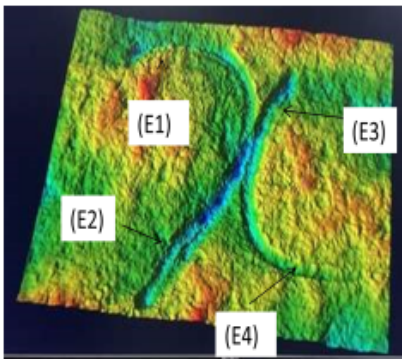


Fig. 29: 3D examination of sample 5

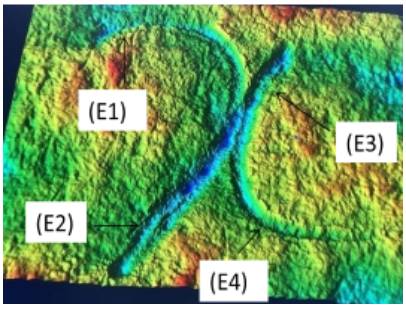


Fig. 30: 3D examination of sample 5

2.13. Sample '6' examination of sample under various magnifications

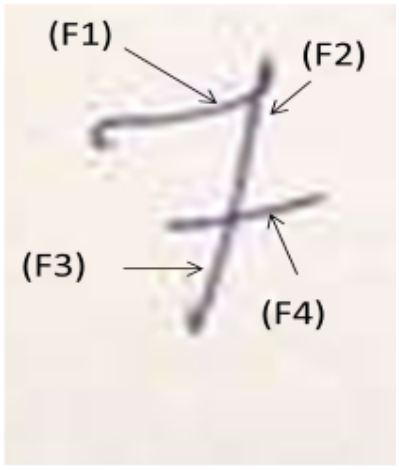


Fig. 31: examination of sample 6 at2X magnification

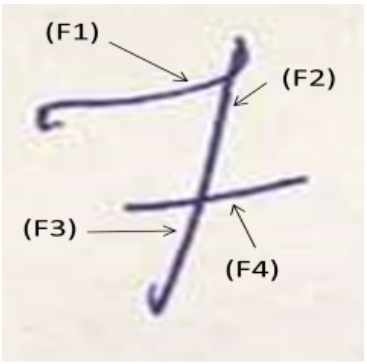


Fig. 32: examination of sample 6 at4X magnification

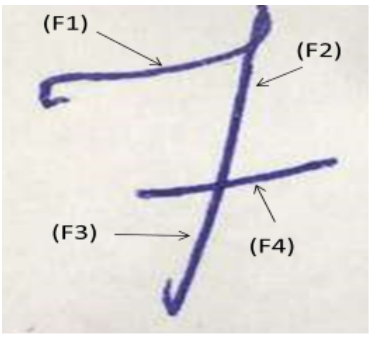


Fig. 33: examination of sample 6 at8X magnification

2.14. 3D examination of sample at various angles

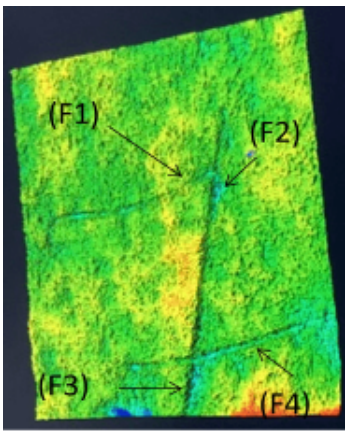


Fig. 34: 3D examination of sample 6

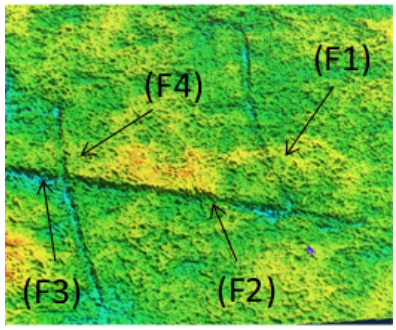


Fig. 35: 3D Examination of sample 6

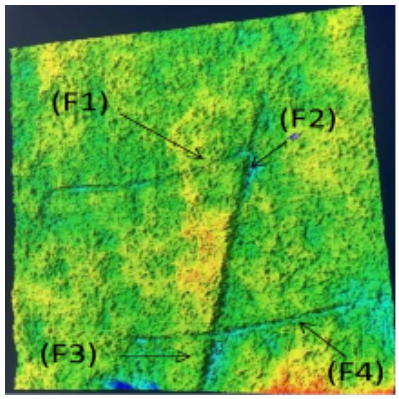


Fig. 36: 3D examination of sample 6

2.15. Sample '7' examination of sample under various magnifications

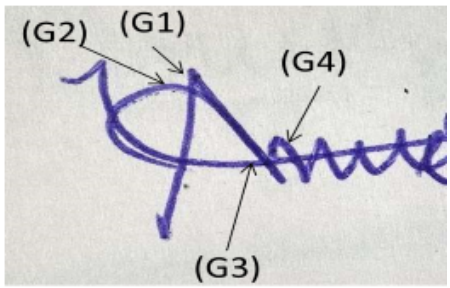


Fig. 37: examination of sample 7 at 2X magnification

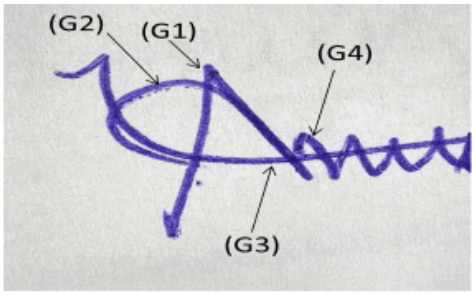


Fig. 38: examination of sample 7 at4X magnification

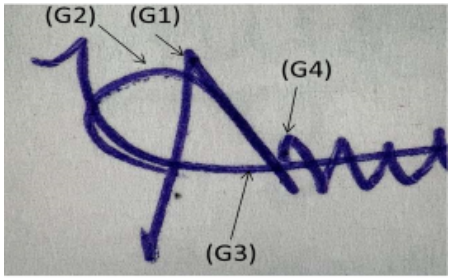


Fig. 39: Examination of sample 7 at8X magnification

2.16. 3D examination of sample at various angles

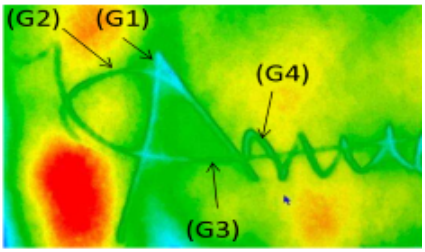


Fig. 40: 3D examination of sample 7

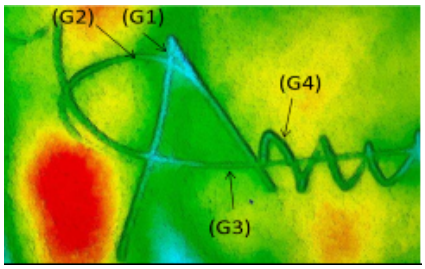


Fig. 41: 3D examination of sample 7

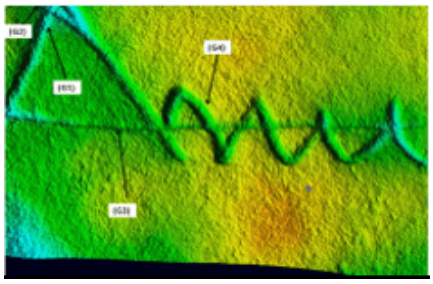
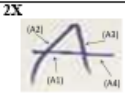
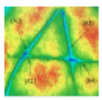
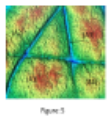
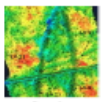
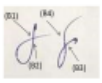
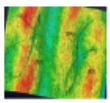
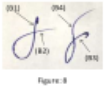
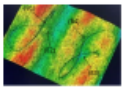
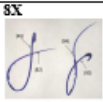
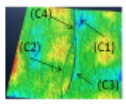
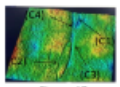
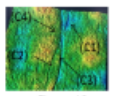
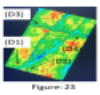


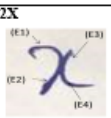
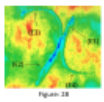
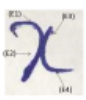
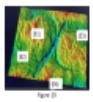
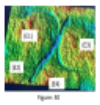
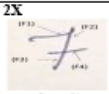
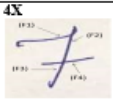
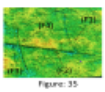
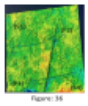
Fig. 42: 3D examination of sample 7

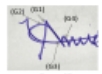
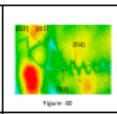
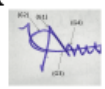
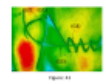
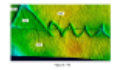
3. Result and Discussion

Thorough examination of all the samples using VSC8000 was conducted at various magnifications which were followed by 3D imaging of samples for determining the sequence of writing strokes where two or more homogenous strokes were crossing/ intersecting over each other. From the figure 1 to figure 6 of sample 1 it was revealed that the edges of stroke A2 were continuously visualized without any break whereas the edges of stroke A1 in each figures were seen interrupted by the edges of stroke A2 at the place of intersection of both the strokes, which revealed that stroke A2 was executed after stroke A1. Further at the intersecting point of stroke A3 and stroke A4, it was observed that the edges of stroke A3 were interrupted/ showed break in continuity by the edges of stroke A4 as the edges of stroke A4 were continuous and without any break which reveals that stroke A4 was executed after stroke A3. From the figure 7 to figure 12 of sample 2 it was observed that the edges of stroke B1 were interrupted by the edges of stroke B2 which was having continuous edges and the edges of stroke B3 were interrupted by the edges of stroke B4 which showed clear continuous edges which revealed that the stroke B1 and stroke B3 were executed prior to stroke B2 and stroke B4 respectively. Now regarding sample 3 it has been observed from figure number 13 to 18 that the edges of stroke C3 & C4 are uninterrupted and continuous in nature whereas the edges of stroke C1 and C2 been interrupted by the edges of stroke C3 & C4 at the intersecting point of both the strokes which reveals that the stroke C3 & C4 was executed after stroke the stroke C1 & C2. From the figure number 19 to 24 of the sample 4 it was observed that the edges of stroke D1 have been interrupted by the edges of stroke D2 at the point of crossing of the strokes which revealed that the stroke D2 was executed after the stroke D1, further the edges of both the strokes i.e. stroke D1 and stroke 2 were interrupted by the stroke D3 and D4 at the point of their intersection. The edges of stroke D3 and D4 were continuous in nature which revealed that stroke D3 and D4 was executed after the stroke D1 and D2. In the sample 5 it was observed from the figure number 25 to 30 that the at the intersection points the edges of stroke E1 were interrupted by the edges of stroke E2 which further extended to stroke E3 with retrace over the stroke E2 and then the edges of stroke E2 were interrupted by the edges of stroke E3 and E4 which revealed that stroke E2 was executed over stroke E1 and the stroke E3 and E4 was executed over the stroke E2. In the sample 6 it was observed from figure number 31 to 36 that the edges of stroke F1 were interrupted by the edges of stroke F2 at the point of intersection of both the strokes which revealed that stroke F2 was executed over the stroke F1, further at the intersection point of stroke F3 and F4 it was revealed that at the point of intersection of both the strokes, the edges of stroke F3 were intercepted by the the edges of trsoke F4 whereas the edges of stroke F4 were uninterrupted and continuous which revealed that the stroke F4 was executed over the stroke F3. In the sample 7 it was observed from figure number 37 to 42 that the edges of stroke G1 were broken or interrupted by the edges of stroke G2 as whereas the edges of stroke G2 were uninterrupted and continuous in nature which revealed that the stroke G2 was executed over the stroke G1, further the edges of stroke G3 was seen discontinuous or interrupted by the edges of stroke G4 at the point of their intersection whereas the edges of stroke G4 were continuous and uninterrupted which revealed that the stroke G4 was executed over the stroke G3.

Test Sample	Zoom/ Magnification Image	3D Image	Result
1	2X 		A1 Stroke is written below the A2 stroke. A3 stroke is written below A4 stroke.
	4X 		
	8X 		
2	2X 		B1 Stroke is written below the B2 stroke. B3 stroke is written below B4 stroke.
	4X 		
	8X 		

3	2X	 Figure: 16	C1 and C2 strokes are written below the C3 and C4 strokes.
	4X	 Figure: 17	
	8X	 Figure: 18	
4	2X		D1 Stroke is written below the D2 stroke. D3 and D4 stroke is written above D1 and D2 strokes.
	4X		
	8X		

5	2X	 Figure: 25 	E1 Stroke is written below the E2 stroke. E3 and E4 stroke is written above E2 stroke.
	4X	 	
	8X	 	
6	2X	 	F1 Stroke is written below the F2 stroke. F4 stroke is written above F3 stroke.
	4X	  Figure: 35	
	8X	 	

7	2X	 	G1 Stroke is written below the G2 stroke. G4 stroke is written above the G3 stroke.
	4X	 	
	8X	 	

4. Conclusion

From the current study it was concluded that the sequence in which the writing strokes executed by a ball point pen can be identified with the help of VCS-8000 depending on the pressure applied while execution of stroke. If the strokes have been executed with an adequate pressure then the sequence of execution of writing strokes can be determined and VSC8000 is a useful technique for identification of sequence of writing strokes and is helpful in solving various criminal cases.

5. Source of Funding

None.

6. Conflict of Interest

None.

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