Computational Forensics: A Vision of 21st Century

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ABSTRACT
In recent years, computational methods have been utilized in various disciplines as diverse as linguistics, chemistry, advertising, vision and many more. Forensic science is also one of the parts of this diverse family which is utilizing computational methods. Although computational forensics as a discipline is at a premature stage, there are lots of possibilities in forensics where this particular discipline can help to cope with new challenges which have arises in the last 2-3 decades. These challenges may be in terms of forged biometric data, incapability of conventional methods, scientific validation of various forensic disciplines after Dauberts hearing or a huge data which is difficult to process by human experts. The list of challenges continues. Fortunately, computational forensics which in nutshell concerns the investigation of forensic problems employing computational methods has potential to address all these challenges. This paper addresses the emerging field of computational forensics, its scope and the various challenging problems of forensics that we have attempted using computational methods.

Keywords: - Computational forensics, computational methods, forensic science.

I INTRODUCTION

In recent years, increasing trends of crime and usage of smarter modus operandi has forced crime investigators and forensic scientists to think unconventionally. Failure of conventional techniques in solving most of these crimes has made the situation even worst. Moreover, some of these conventional techniques have also been criticized by the court of law due to lack of proper scientific basis. Computational Forensics seems to be a solution in such a scenario which facilitates a human expert with a smarter way to combat with the upcoming challenges.

Computational Forensics is one of the emerging fields of Forensic Science, which utilizes computational methods for combating challenges of various forensic problems. From computation methods, we mean the theory and algorithms of mathematics, statistics and computer sciences. Thus Computation Forensics involves modeling, simulation, computer based analysis and recognition in context of forensic problems. The problems of forensics may range from crime scene reconstruction to analysis of evidences and their comparison and identification. Computation Forensics can address all of these problems in much efficient and smarter way than it could be solved through a conventional technique. Computational methods are advantageous in the sense that it utilizes human experts' domain knowledge to train a machine to develop reasoning ability and recognition task.

II CONVENTIONAL FORENSICS VERSUS COMPUTATION FORENSICS

Forensics or forensic science is the application of science and technology for the purpose of court of law. Depending on the area of application forensics may be termed as forensic physics, forensic chemistry, forensic biology or forensics with any other discipline. The field of forensics is challenging in the sense that, there may be very less information or evidences available at scene of crime. Moreover, the available evidence may be the only available evidence which could lead it to the crime, that too in chaotic environment. Other challenges may include subjectivity of opinion, intra product variation of the same source and its differences with inter product variation and lack of proper databases.

Most of the conventional forensic techniques are based on manual examination of evidences. Some tools are though available for examination but that too needs advancement, especially in the disciplines of forensic document examination, forensic fingerprint examination and forensic physics. Computational Forensics, on the other hand, does not aim to replace human intervention during examination but to assist in basic and applied research, for instance, in providing scientific basis to the examination and to support forensic examiner in daily case examination as well as better representation of evidences for court testimony [1]. Moreover, Computational Forensics helps a forensic examiner in following ways [1]

(a) Analyze and identify traces in an objective and reproducible manner.
(b) Assess the quality of an examination method.
(c) Report and standardize investigative procedure.
(d) Search large volumes of data efficiently.
(e) Visualize and document the results of analysis.
(f) Assist in the interpretation of results and their argumentation.

III THE GAMUT OF COMPUTATION FORENSICS

Computation methods may be applied in various disciplines of forensic science including forensic document examination, forensic physics, crime scene reconstruction and digital forensics. We have successfully applied it in the following disciplines

(a) Forensic Examination of Fraudulent Alteration- Alteration in document is an old age problem but in the era of digital technology too, alteration in documents like cheque, contracts and will are frequent. In [2], we have proposed an algorithm to detect such an alteration made by ball-point pens having ink of similar color. The problem of alteration detection was addressed in the framework of image processing and pattern recognition. Image of the ink strokes in question was captured and enlarged to some extent using an image processing workstation coupled with microscope. After preprocessing, color and texture features were extracted from both the strokes to know whether the two strokes are made with same pen or different pens. After analysis of quality features for the targeted task, it is subjected to classification or detection. Three classifiers, namely, nearest neighbor, Multilayer Perceptron and Support Vector Machine have been utilized for detection task. Results have been summarized in Table 1.

Table 1
Performance of different systems for alteration detection

System	Accuracy	False Acceptance Rate	False Rejection Rate
Nearest Neighbor	85.51	05.55	21.89
Multilayer Perceptron	86.43	12.18	14.96
Support Vector Machine	89.36	06.72	14.56

(b) Forensic Signature Verification- Signature is one of the oldest means of person identification. It is originated much before the concepts of Biometrics. Problem of signature verification is popular in both the fields of forensics and biometrics due to its vast area of applications. In [3, 4], we have proposed two different systems for signature verification proposing two novel features, namely, signature morphology and surroundedness feature. These features are capable of capturing geometric shapes and line quality specific to the writer. We have utilized two popular databases, namely, CEDAR and GPDS databases to examine the efficacy of the proposed systems. Results have been summarized in Table 2 and Table 3.

Table 2
Performance of signature verification system on CEDAR database

System	Number of Signer	Accuracy	False Acceptance Rate	False Rejection Rate
Signature Morphology	55	88.41	11.59	11.59
Surroundedness Feature	55	91.67	08.33	08.33

Table 3
Performance of signature verification system on GPDS database

System	Number of Signer	Accuracy	False Acceptance Rate	False Rejection Rate
Surroundedness Feature	300	86.24	13.76	13.76

(c) Forensic Writer Identification- Identification of writer is an important forensic problem. Identification of writer based on handwriting on anonymous letters and other documents may directly link the commission of crime with perpetrator. In [5], we have proposed text independent writer recognition system based on sparse model. A dictionary of all possible curves, we call it, fraglets have been learned and writers have been idendified based on the distribution of fraglets specific to an individual writer. The system has been tested on a popular database, namely, IAM database of 657 writers and results are summarized in Table 4

Table 4
Performance of writer identification system

System	Size of dictionary	Accuracy (Top 1)	Accuracy (Top 10)
Sparse model based system	200	88.43	99.24

(d) Other Forensic Disciplines- We have also proposed a few systems for detection of counterfeit cheques and other security documents. Moreover, a system was designed for particle size distribution of soil based on the concepts of mathematical morphology.

IV CONCLUSION

Computation Forensics as a discipline though is not in mature form, its potential in solving complex forensic problems cannot be ignored. Moreover, it provides scientific basis to various conventional concepts of forensics. Using the techniques of Computational Forensics, various existing concepts may be statistically validated. However, there is need to work forensic scientists and computer engineers together for the advancements of the field. Though in some of the disciplines of forensics, the concepts of computational methods have been utilized, new areas need to be explored.

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