FODET: Forensic Tool for Determining Suspects or Objects in Crime Scene Investigation

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Abstract— *Crimes are committed in society all around the world, and some crimes also disturb the peace and order of society as well. It is important to identify the suspects quickly and catch the criminals, and then conduct trials to put them behind bars as a punishment when necessary, especially when the crime is severe. However, accurate and real-time person identification still remains to be a problematic issue, even if digital images of the crime scene are available. With the available information (CCTV images, stored images of suspect etc.) in this regard, we have learned that it is possible to make an accurate identification of a person if object recognition (tattoos, necklace etc.) is done along with face recognition. This holistic approach would be more reliable since multiple aspects of the same person or crime scene are verified. In our work, we have designed and developed a computer-based system, called FODET for determining person or objects involved in crime, with new ideas that make this tool very useful in practice. FODET is user-friendly tool and designed to meet above challenges, while helping in identifying suspects and objects involved in crime with high level of accuracy. In addition to face recognition, detailed object recognition along with image differentiation, boundary based recognition is proposed and implemented in our work. We have conducted tests to show that the results are accurate, and the system can also be configured to suit the needs of a crime investigation department. We believe that our work has a lot of practical application and it could be adopted in the future by state police or crime investigation departments.*

Keywords— Face Recognition, Crime Investigation, Image Analysis, Similarity Measure, Object Detection

I. INTRODUCTION

Crimes are the unfortunate reality of human society, and a growing number of crimes now-a-days demand forensic and investigative techniques that were not available a few decades back. Quick and accurate identification of the evidence available at the crime scenes, for example finger prints, or a weapon such as knife, a possible suspect at the scene is a critical phase in any investigation.

Manual identification or verification techniques to aid in such investigations are cumbersome and time-intensive. Timely and accurate results are important to an investigation team, especially if the crime itself is of a critical nature and leads need to be followed up for further investigation. Most crime investigation divisions around the world are adopting computer-assisted techniques, and leveraging the capabilities of IT to make the investigation phases quicker, accurate and developing more effective techniques to prevent further crimes.

We found that although IT-based solutions exist, there is little work done in developing a holistic tool – one that can help in person as well as object identification. It is well-known that not only the person committing the crime, but the evidence (of weapon) used in crime is equally important. Moreover, there could be object at the crime scene itself that could provide further clues on further investigation, for example a unique necklace worn by suspect, or type of cigarette person is holding in a CCTV captured image etc.

The Computer-based forensic tool, called FODET we have developed in this project is addressed to meet such needs. The tool is easy to use, uses various algorithms for identification and verification of people and objects. One could configure the tool, and use the tool for quick identification of suspects by checking an archive of previously collected images from CCTV, spy cameras, or images that were publicly available. The tool can also be used to identify images at crime scenes – missing or forgotten items by criminal. The tool provides high accuracy, and thus a very useful tool of our society

II. MOTIVATION

Our primary motivation to undertake this project was to help forensic investigators solve crimes, accurately and as quickly as possible. Manual checking of a suspects identity or face features is time-consuming and may miss details that could be identified by using technology. Thus we planned to develop an IT-based forensics tool to help determine suspects and objects at a crime scene. Another, but equally important motivation was that such tools need to be easy to use and effective for the purpose of any investigation. Hence, we were motivated to develop a holistic tool, one that addresses a range of different things involved in a forensic investigation – person, objects, person carrying specific objects or object missing from crime scene etc. We believe that considering various such directions in investigations will surely lead to quicker identification of the criminal, and prove to be an effective approach to solving cases.

III. APPROACH AND CONTRIBUTIONS

Inability to accurately recognize a person (suspected criminal) using an information technological (IT) system is the main problem we are trying to address. Although many systems exist, accurate and precise real time person identification still remains a challenge in practice. Many cases in recent history (including Boston bombing), and regular burglaries bear evidence that no reliable solutions yet exists and this is still an active area of research. Our tool is a step towards providing a practical, quick and usable system during crime investigations.

A. Overall Solution

Overall objective of our solution is to provide precise and accurate identification of people by using a highly technological system with efficient algorithms implemented for the purpose. Furthermore the components of the system should be working together in close relation to present a highly productive and useful system that can help in crime investigation

B. Proposed Solution

Our solution provided the following features - accurate person (criminal) identification with the use of face recognition, facial validation, object recognition, boundary based recognition and image differentiation. The tool has several useful functionalities, database connectivity to deliver requested information and having a well designed and developed interface to make it a useful tool in practice.

C. Project Scope

The scope of the project focuses on serving officials involved in criminal identification to make use of this system to accurately identify criminals based on several characteristics of the criminal and his/her belongings. We have narrowed down the scope for this project to identify/recognize faces and objects. The object could be something that the person carries or could object left behind (or moved) during crime. We have integrated these into our system to facilitate investigation.

D. Project Objectives and Evaluation Criteria

We set the following objectives and performance criteria when we started designing the FODET tool. Not surprisingly, we wanted to build a prototype that could deliver results accurately and quickly.

- Achieving high success rate for face recognitions
- Implementing detailed face and object detection
- Presenting a percentage match so that false positive can be eliminated after examination
- Implementing facial validation and reporting the similarity index
- Implementing scene differentiation
- Implementing object recognition, differentiation and identification
- Implementing shoe print recognition as an example
- Making the tool extendable and practical to use

E.Similar Systems Study

In order to identify needs and novel features for our new system, we studied several previous similar systems and compared the crucial investigations features that have been implemented in each. This study helped us identify the limitations of existing work, improvements, suggestions and knowledge for future research that needs to be carried out. A robust automatic face recognition system for real-time personal identification is presented by (Li et al. (2006). Robust real time object detection is proposed by Viola and Jones (2001). A Rapidly Trainable and Global Illumination Invariant Object Detection System are developed by Pavan et al. (2009). Face recognition across a pose is reviewed

by Zhang and Gao (2009). An integrated automatic face detection and recognition system is developed by Koh et al. (2001). A Trainable System for Object Detection is presented in Papageorgiou and Poggio (2000). An Automatic shoeprint matching system for crime scene investigation is presented by Deshmukh and Patil (2001).

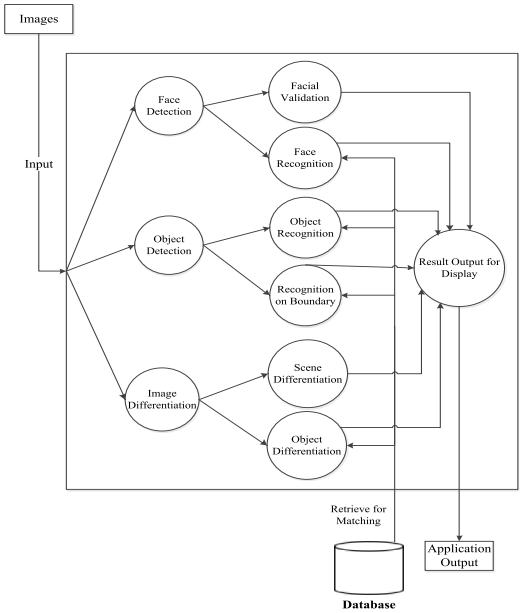

Figure 1. Design overview of FODET tool

Limitations were noticed in previous projects, and hence we were motived to overcome these in our project. Figure 1 shows the overall working of the system. First, the input image is clarified and passed through the system with required procedures put into use. The connected database associates the input image with relevant matches stored within it methodically. Table 1 defines the main functionalities we have addressed in this project.

Table 1. Meaning of Functionalities Addressed

Term	Meaning
Face detection	Given an image, face detection is to determine whether or not there are any faces in the image and, if present, we return the image location and extent of each face
Object detection	Given an image it detects figuratively similar objects from the available images stored in archive for similarity matching
Face recognition	Type of pattern recognition of a person's face which is recorded in a database for future attempts to determine or recognize a person's identity when the face is viewed for clarification
Object recognition	Given an image (of an object), object recognition identifies as to what exactly the object is and how does it appear in the context of the given set of matched images
Face validation	The process of matching a known individual's face features with the same person's face or similar face that may exist in an archive of images
Scene and object differentiation	Differentiation of images (and their features) based on their similarity and content

IV. FODET DESIGN DETAILS

Requirement specification were first identified and then carefully converted into a design that maps all the requirements. MVC (Model-View-Controller) architecture was selected as the software development architecture to facilitate development. By using this architecture for this software application development, the complexity of design, flexibility and reuse of code can be done successfully. This would also support pushing back of data to multiple views by model as data gets updated as shown in Tijms (2011). Therefore data can be visualized in many forms.

In order to achieve detailed face detection Viola Jones algorithm is selected with the use of Haar based cascade classifiers. Viola Jones algorithm is widely used for real time face detection as its detection is fast although it may take time to train, as describe in Viola (2001). Moreover Haar based cascade classifiers implemented within the code increase the accuracy of detection by aiding to detect the relevant facial features.

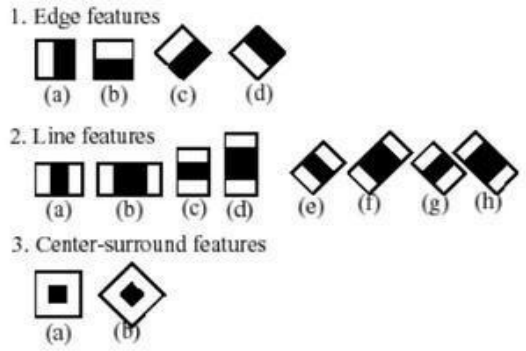

Figure 2.Haar-like features (Minor, 2011)

Many Java compatible APIs such as Java Advanced Imaging (JAI) and Java Media Framework (JMF), Java Machine Learning Library (JavaML), OpenCV, JUnit and SQL-JDBC4 along with JavaCV were taken for both face/object detection and recognition. However APIs available via AForge were not used as they are heavily based to support C# framework. APIs and frameworks that support Java were selected at different scales based on the requirements arising at each point of programming.

Surf (Speeded up robust features) object recognition framework was selected over MATLAB - Computer Vision System Toolbox for detailed object detection and recognition due to its robustness and extremely rapid object detection. It was found out through research that MATLAB - Computer Vision System Toolbox (Computer Vision Library, 2014) might not provide feasible configurations to object recognition with Java up to the level provided by Surf. Surf outperforms previously mentioned schemes with respect to its repeatability, distinctiveness, and robustness (Computer Vision Library, 2014).

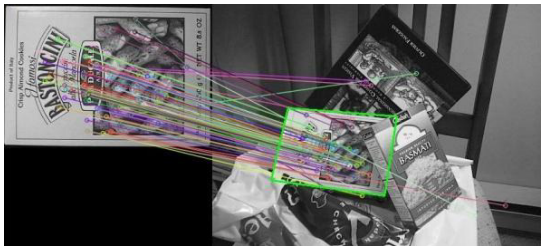

Figure 3. Surf - object recognition (stackoverflow.com, 2012)

Standard PCA, or Eigenfaces algorithm was selected for face recognition and validation, having being compared the suitability over others like geometric & template matching, Discrete Cosine Transform (DCT), Linear Discriminant Analysis (LDA), Locality Preserving Projections (LPP), Gabor WaveletKernel and Independent Component Analysis (ICA).

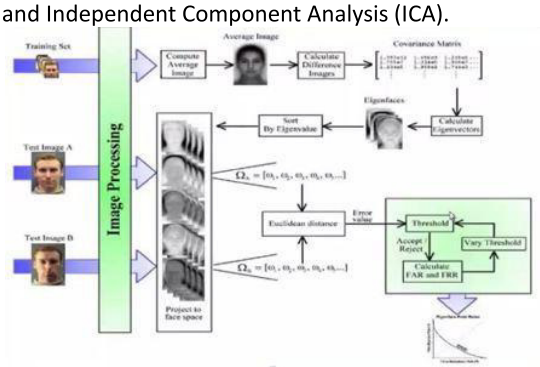

Figure 4. PCA/IPCA architecture (GRIETCSEPROJECTS, 2011)

Geometric techniques use vectors and might be unstable and sensitive to disturbances of facial expressions at varying pose. Template matching Kumar (2006) though is fine for frontal view matching it is not good at non-frontal view matching. LDA requires larger storage of faces and requires high processing time and might lead to low recognition rate due to lack of generalization. Global properties like coloring, width and length are more easily captured by PCA than ICA.

Results have shown that Eigenfaces methods are robust to low resolution images and over a wide range of parameters and produce good recognition rates on various databases. PCA as presented in Kumar (2006) has the capability to handle high resolution images very efficiently. The statistical information and implementation of other techniques were not that prominent and therefore considering all these PCA was selected for face recognition

V. IMPLENTATION DETAILS

In this section we give details of the tools and APIs we have used to develop the tool. As shown in Table 2, since there is a large body of work in image recognition we used some existing APIs that have good performance. These had to be integrated to make it suitable for a forensic investigation tool.

Several different APIs (application programming interfaces) had to be used for developing core functionality of our application. Based on different requirements and in order to enhance the user activity with the application, APIs that could be integrated successfully with Java development platform were selected. OpenCV along with its

wrapper for Java, JavaCV interconnects most of the sub-components in our tool.

JAI (Java Advanced Imaging) library was used mainly for object differentiation while JUnit library was helpful for object recognition to a great extent. SQL JDBC driver (sqljdbc4) was used for database interconnection with the application. Colt, rs2xml, thumbnailator and opencsv are some of the other library APIs that were used in the application development.

Table 2. API's and algorithms selection in brief

Objective	APIs and algorithms
Face detection	Viola Jones algorithm with Haar based cascade classifiers
Detailed object detection and recognition	Surf (Speeded Up Robust Features) detector algorithms and APIs
Face recognition and validation	PCA (Principal Component Analysis) / Eigenfaces
Shoe print recognition	Time series (DTW) and cosine similarity with linear regression
Scene and object differentiation	Java Advanced Imaging (JAI)
Maintenance of a suitable image database	Microsoft SQL Server with Java JDBC (Java Database Connectivity)

VI. EXPERIMENTS

It is always important to verify that a system or an application is functioning accurately as expected and producing expected results. We did three types of tests on the application developed. They were unit testing, integration testing and validation testing. Unit testing assured that each component of the system is working perfectly as expected while integration testing assured that the union of all the components together to perform the tasks came out successfully as expected. Validation testing assured accurate transformation of data into information prior to storage and use.

In order to make sure that the face recognition functions successfully with high accuracy even under drastic conditions like low light, slight posture variations, extreme variations of expressions, background variations including person's outfit for the image, various different image databases were used. Spacek (2008) image database was used mainly as it had four different testing image databases within it, in order of increasing difficulty for recognition. The system however responded successfully with accurate results over all the databases and image condition variations.

Many different test cases were constructed to demonstrate the efficiency and the affectivity of the system. Mainly the test cases were based on the functionality as components and overall when integrated. Face recognition test results showed high accuracy even under drastic conditions. Facial validation also gave highly productive results even at variations of PIE (pose illumination and expression). Object recognition and boundary based recognition test results proved to be highly effective when used along with face recognition for person identification.

Next we provide some examples of how the tests are carried out. A demonstration of our work would make this easier to understand.

Figure 5. Face recognition (96.71% match)

Figure 6. Face validation example

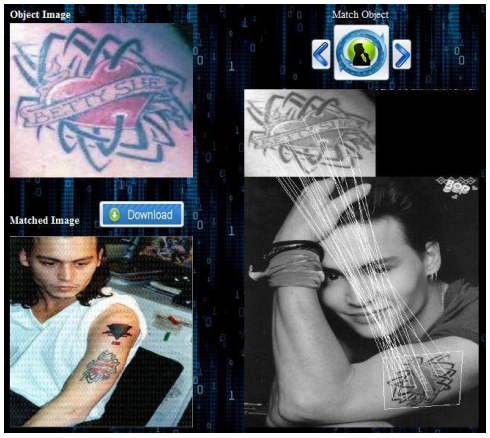

Figure 7. Object recognition (tattoo selected to find match)

Other recognition tests carried out on scene/object differentiation, image property adjustment, authentication and database views, height determinations also gave comprehensive results aiding previously mentioned main recognition modes. The system was designed and implemented to facilitate individual recognitions for person identification as well as collaborative recognitions for person identification. Overall, the main component of face recognition gave an overall accuracy above 95% for the test cases carried out while the system as a whole gave accuracy around 90% for the recognitions.

Figure 8. Scene/object differentiation (watch found in different CCTV images of same area)

VII. ANALYSIS AND FUTURE WORK

In this section we provide a conclusion and some ideas for future work

Java platform neutral, programming language was chosen in a Windows based environment for the software application implementation. After the thorough investigation and analysis the best suitable algorithms, APIs and software development methodology were selected. Mainly OpenCV, JavaCV, JUnit, SQLJDBC, JAI APIs were used for implementation but to suffice other small scale requirements few other APIs were also integrated. For face detection Viola Jones face detection algorithm was chosen with Haar cascade classifiers. SURF framework was selected for the detailed object recognition while face recognition and validation were carried out with the use of Eigenface / PCA method. Recognition on boundary was implemented mainly for shoe print recognition, using time series and dynamic time warping. Evolutionary prototyping was selected as the methodology for software development after making an analysis of the functional requirements and the context of the project. This person identification system implemented covers a wide range of new technical programming usages for efficient real time criminal recognition.

After being able to analyse all user requirements and then deciding on system requirements and the way of designing, finally a highly successful person identification system was implemented. The implemented and tested system produced highly efficient and productive results with high degree of accuracy. Overall as a system and also as separate components, around a success rate of around 90% was achieved. This is a great achievement and is evidentially a software application that could be directly applicable to the criminal or person identification to the best of extent in real time. This solution developed is highly applicable to the identified problem domain and by applying it to real world scenario highly productive and trustworthy results can be gained.

All in all a highly successful and a valuable artefact or a software solution was developed giving the solution to person identification and criminal identification in detail. The overall solution presented is of high standards because the results provided by the solution are highly accurate, effective and efficient.

As part of future work, the system could be enhanced by integrating finger print recognition, real time criminal database, palm print recognition etc. Additional image enhancement methods can be added to facilitate better object recognition. Advanced security measures can be integrated into

this system to address country or police department specific needs.

VIII. CONCLUSIONS

FODET is user-friendly tool designed to meet the challenges in crime scene investigation. Currently it does face recognition, detailed object recognition along with image differentiation, boundary based recognition and produces user-friendly reports to user. We have conducted tests to show that the results are accurate, and the system can also be configured to suit the needs of a crime investigation department. We believe that our work has a lot of practical applications and it could be adopted in the future by state police or crime investigation departments.

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