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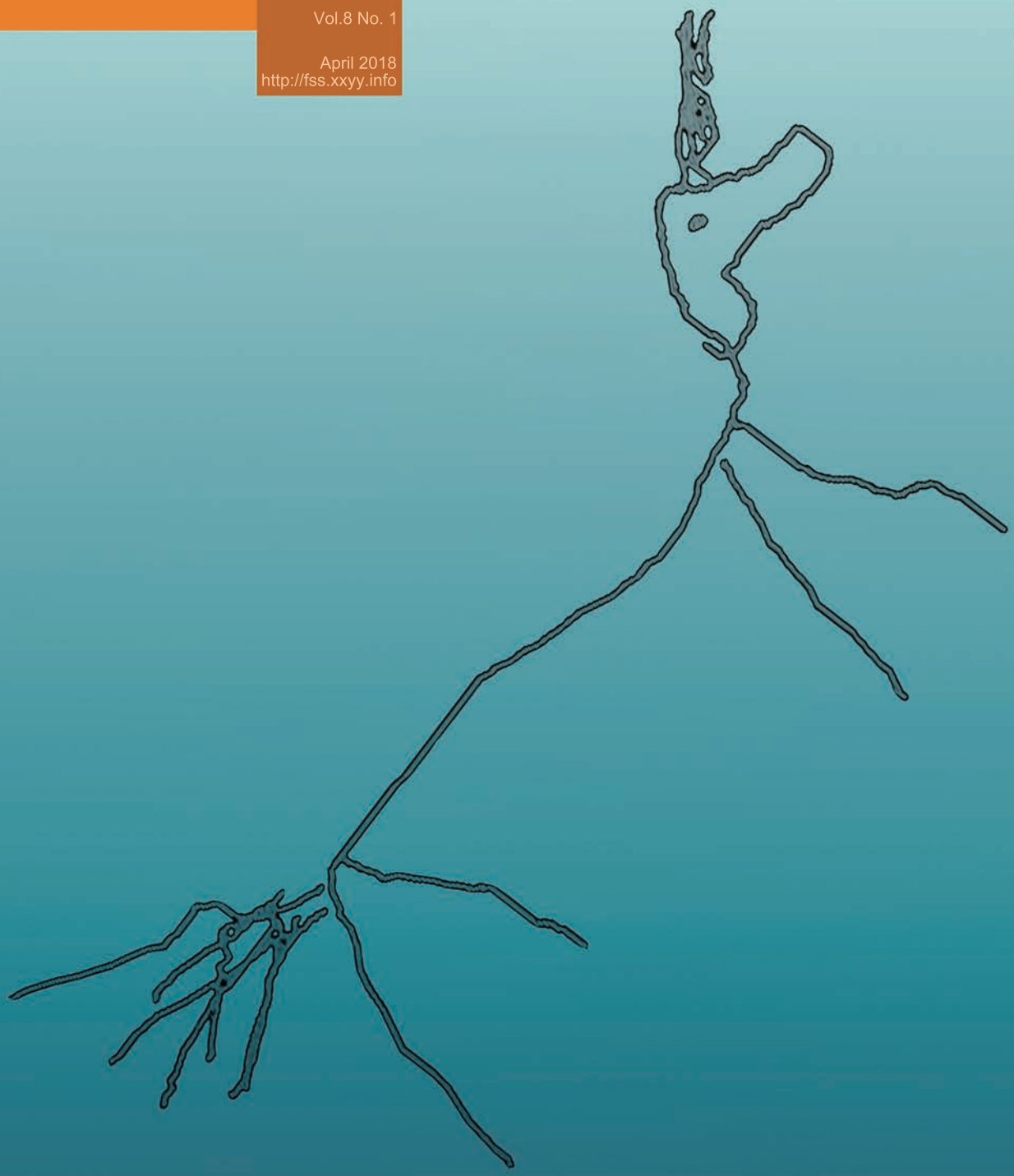

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Application Status and Intelligent Trend of Digital Forensic Pathology in Identification Practice

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ABSTRACT The traditional forensic identification methods rely mainly on the naked eye observation and empirical judgment of the appraisers in the process of autopsy and histopathological examination. The impartiality and scientific nature of the identification opinions thus formed are often questioned, often causing the parties to suffer due to evidence. Or conflict with the case handling party. Forensic pathology and medical imaging, computer simulation and other multidisciplinary integration formed a series of new digital technologies, which are revolutionizing forensic identification technology.

KEY WORDS Forensic pathology, Virtual anatomy, Multi-rigid body simulation, Finite element analysis, FEA, Forensic science

1. INTRODUCTION

Forensic autopsy is a fundamental method and gold standard for recognizing clear causes of death. The traditional forensic identification methods rely mainly on the naked eye observation and empirical judgment of the appraisers in the process of autopsy and histopathological examination. The impartiality and scientific nature of the identification opinions thus formed are often questioned, often causing the parties to suffer due to evidence. Or conflict with the case handling party. Some of the lesions may not be able to obtain enough powerful information through autopsy, and the traditional autopsy is a destructive examination. For centuries, it has been resisted and opposed by the families of the deceased, especially by some religious cultural traditions [1].

Forensic pathology and medical imaging, computer simulation and other multidisciplinary integration formed a series of new digital technologies, which are revolutionizing forensic identification technology.

At present, virtual anatomy, multi rigid body simulation and finite element analysis are the most mature technologies.

2. VIRTUAL ANATOMY

With the development of medical imaging techniques such as CT and MRI, it provides a non-invasive/minimal invasive cadaveric examination method for forensic medical examination—the forensic virtual anatomy technique that can clearly observe the cadaver organs, bone lesions and damage, and can save the parts of the body image data, is conducive to late re-examination and consultation, the detection of forensic injury and the cause of death has a great value.

In the 1990s, Dr. Thali *et al.* [2] of the Institute of Forensic Medicine at the University of Bern, Switzerland, first proposed the concept of virtual anatomy and formed a theoretical system. Current virtual anatomy techniques include optical three-dimensional surface scanning, 3D photography, CT scans, and MRI scans. They make full use of the advantages of new technologies and multi-technology integration to address causes of death, forensic pathology, life response, injury reconstruction, such as forensic focus. Many countries in Switzerland, the United States, Japan, the United Kingdom, and Australia [2-5] have achieved certain research results in terms of damage detection, injury model estimation, and cause of death identification.

3. MULTI-RIGID BODY SIMULATION

With the development of economy, the increase in the types and number of vehicles, the incidence of traffic accidents and the number of dead and injured have also shown an upward trend, which has become an important factor affecting social development and people's lives. The identification of traffic accidents has also gradually risen to a forensic pathology, the focus identification project. In recent years, with the development of computer hardware and numerical simulation technology, it has become technically possible to reconstruct traffic accidents through digital reconstruction methods. The digital photogrammetry technology

and multi-rigid body dynamics simulation technology can reconstruct the accident scene and digitally simulate, simulate and visualize the collision and injury process in the accident, thus assisting in the development of the forensic identification of traffic injuries, and the accuracy, objectivity of accident identification, and impartiality and scientific treatment of accident liability.

Since the 1970s, research institutes in the United States, Europe, Japan, and Australia have used multi-rigid body dynamics methods to perform vehicle crash tests and impact tests of occupant protection devices, which have caused structural deformation and crashworthiness of vehicles in collision accidents. As well as issues such as safety, a simulation analysis was carried out to reveal the injury mechanism of the vehicle's personnel, formulate damage assessment standards, and propose improvements to the vehicle design. Since the beginning of the 21st century, European and American research institutions have begun to use multi-rigid pedestrians and vehicle models to reconstruct real road traffic accidents, simulate car-pedestrian collisions, reproduce the process of injury caused by traffic accidents, and determine the posture of pedestrians, the collision speed and the braking state of vehicles, etc. And analyze the impact of factors such as vehicle type, body shape, initial posture, and vehicle braking status on pedestrian distance, location and human injury after collision. [6-9]

The research on simulation and simulation of multi-rigid traffic accidents in China started relatively late. The digital reconstruction of car-pedestrian crashes was mainly carried out after 2002. Tsinghua University, Jilin University, Hunan University, Third Military Medical University and other research institutes have independently constructed or apply commercial models to reproduce the real-world case of car-pedestrian collision accidents. The research content includes the relationship between vehicle speed and body throw distance. The characteristics of different vehicle speeds and different vehicle models causing damage to the outside of the car are discussed, including the possibility of protection from outside the vehicle. [10-13]

4. FINITE ELEMENT ANALYSIS (FEA)

The analysis of human forensic pathology by traditional forensic pathology mainly depends on naked eye observation, autopsy, light microscope observation and empirical judgment. The subjective arbitrariness is strong, and the understanding of damage is mostly limited to damage morphology. [14]

The finite element model of the human body is composed of the decomposition and reorganization of human tissues in unit discrete and three-dimensional modeling. It can perform load simulation on specific boundary conditions, calculate the effect of external forces on human tissue, and finally obtain various Human biomechanical results. The finite element method is of great help in reconstructing and predicting the locations, forms, and degrees that may occur in human injury, improving the shortcomings of traditional forensic pathology, and providing a favorable reference for forensic identification of injury.

Since the 1970s, the finite element method has been applied to the modeling and damage biomechanics of the human head, spine, etc. The research scope has gradually expanded to the pelvis, thorax, and joints of the limbs and other structures. In addition to the skeletal system, finite element models have been constructed for cardiovascular, ocular, gastrointestinal, pulmonary, hepatic, renal, and even placental sites and lesion analyses have been performed. At present, finite element modeling and analysis methods have achieved certain results in the following biomechanical studies of common injuries, including accelerations caused by acceleration/deceleration of the head and injuries caused by rotational motion, and internal organs caused by the external force of the chest and abdomen, injury to blood vessels and damage to the thorax, spine, pelvis, and joints of the limbs and attachments caused by external violence. [14-18]

The study on the relationship between finite element modeling and human injury started relatively late in China. In recent years, there have been reports of research results in succession, mainly focusing on the fields of engineering and material mechanics, traffic injury prevention and clinical trauma research. The Southern Digital Medical University, the Third Military Medical University, and Shanghai Jiao Tong University have developed digital avatar programs for medical research, clinical treatment and teaching, and have achieved corresponding research results. The human biomechanical model research plan is used to simulate the collision between different parts of the vehicle and the human body in a traffic accident, to perform numerical response analysis and to study the injury mechanism of human injury. [19-20] In addition, based on the research needs of weapon damage protection; relevant agencies in China have also conducted relevant research on chest finite element modeling and damage analysis. [21-22]

However, there is a certain gap between the focus of the above research work and the damage morphology, damage mechanism, and biomechanical analysis of damage in forensic science research.

5. DISCUSSION

Through virtual anatomy technology, human injury can be clearly detected and the damage situation can be effectively evaluated. Through multi-body dynamics simulation technology, road traffic accident reconstruction can be effectively carried out, and the occurrence of real accidents and the damage of human injuries can be restored. Through finite element modeling and analysis techniques, the damage can be dynamically and quantitatively analyzed from the perspective of biomechanics to predict the site of injury and observe the occurrence and development of the injury. The formed electronic evidence can be displayed in the form of images and dynamic effects, clear, easy to understand, easy to understand the illegal medical personnel involved in the litigation process, and greatly enhance the quality of the identification of the case. In view of the differences in the principles, equipment, and

concerns of the various digital technologies mentioned above, the joint application of multiple digital technologies to complement each other has become a research hotspot and development trend in the international forensic science field. [23]

According to relevant reports [24], the development of various new technologies in forensic pathology digitalization still has deficiencies, and each has its own advantages over traditional forensic identification. The combination of traditional forensic identification and digital technology can provide a more scientific and effective theoretical basis for forensic identification.

The preliminary results based on the concept of "virtual reality", such as autopsy multi-slice spiral computed tomography (MSCT) and magnetic resonance imaging (MRI), have been introduced and evaluated in forensic medicine [25]. Forensic pathology new molecules and innovative technologies are also in full swing [26]. While some research teams have recently begun to use artificially related technologies to conduct new research on forensic pathology, for example, to improve the quality of autopsy reports through computer proofreading procedures to identify errors [27]; to vector quantifiers to identify endometrial malignancies [28]; to establish a diagnostic decision support system through logical programming, supplemented by a computational framework based on an artificial neural network, establishing a model for assessing thrombophilic propensityshment of a diagnostic decision support system supplemented by formal agendas based on logical programming methods for knowledge representation and reasoning, supplemented by a computational framework based on artificial neural networks, and its model is quite accurate in assessing propensity to thrombogenicity. This model can properly classify patients who do present with pathology and can classify disease deletions [29]; *etc.*

6. CONCLUSION

At present, forensic pathology digitization technology is still in the development stage. Virtual anatomy, multi-rigid body simulation, finite element analysis and other technologies all have certain flaws and technical blind spots. Digital technology cannot completely replace traditional forensic identification and research methods. Combining digital technology with traditional identification methods, a new injury analysis model including expert system, data information system, and computer system was formed to ensure the forensic medicine and the rigor, objectivity, and accuracy of scientific evidence formed.

In less than a decade, big data in medicine has become a phenomenon, and many biomedical disciplines have their own papers on this topic. Outlook and debate are booming. However, real big data research is still very rare in medicine and does not meet all expectations. On the one hand, technologies that are usually proposed for big data (such as machine learning techniques) should support ambition for personalized, predictive and preventive drugs. Most of these technologies are not new, and they have been more than 50 years old for the oldest technologies. On the other hand, several issues that are closely related to the nature of big data and inherited from other scientific fields (such as artificial intelligence) are often underestimated if they are not ignored. In addition, some papers have adjusted almost identical enthusiasm for big data, and because they describe the risks, they deserve attention. [30] In this context, forensic science is still waiting for its position paper and a comprehensive overview of what big data can bring in this area. The current situation requires that definitions and actions reasonably guide the research and practice of big data. This is an opportunity for true interdisciplinary cooperation.

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A Generic Process Model for Botnet Forensic Analysis

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ABSTRACT Botnets are becoming more hazardous in cyber crime when compared to other malicious activities. Security against botnets is a major concern. Botnet forensics is young science which can answer questions about how, what and where of damage done by bots. The forensic system deals with capturing, recording, and analysis of botnet traffic. This paper outlines the process of Botnet forensic analysis and its implementation. A generic process for botnet forensics is proposed based on previous digital forensics models. The specific research gaps existing in implementation are identified and presented as challenges. The contribution of this work is that it presents an overview on botnet forensics analysis and implementation which will be more valuable for security.

KEY WORDS Bot, Botnet, Analysis, Forensic science

1. INTRODUCTION

Botnet is an army of infected computers that take instructions from a botherder. A botherder is corrupt hacker who uses the botnet for financial gain or as a destructive behavior of civilization and the Internet community without ethics. The bad guys have been using the latest killer web application, is the advanced security Web technology. Many of the security professionals who pioneered the fight against botnets are demoralized by the realization that taking out the C&C [1] does not helps. Botnets a call to Action (Command and Control) server is less effective now days. Botnet infection is adaptive means for chain to chain system. Single virus/worm spread the infection another module through malicious code that prevents previous antivirus action [2].

Social networking sites like orkut, facebook, skype and Google blogger were infected by distributed denial of service attacks, spam etc. Computer forensics was introduced by law enforcement with proper guidelines of judicial system [3]. Computer forensics involves protection, detection, mining, records, and analysis of computer data. Botnet forensics analysis is a natural extension of computer forensics. Botnet forensics analysis is a permanent monitoring process that deals with capturing, recording, and analysis of botnet traffic in packets format. It can also indicate alerts when thresholds (maximum limit) are exceeded. If the present attack could not be prevented, the fundamental information is used to defend against similar attack in future event. Botnet forensics can be used to evaluate how and where the attack occurred, who was culprit, duration of the exploit, and the line of attack. Botnet forensics can be used as a device for monitoring the activity of botmaster and hacker, business transaction analysis and investigation of irregular performance issues sources. Botnet forensics involves postmortem research of the attack means notitia criminis (after crime announcement) which takes particular duration of action and way of tackle for particular cases. Botnet forensics and the attacker both are at the identical proficiency altitude. The hacker uses a set of tools to launch the attack and the botnet forensic authority applies similar tools to explore the attack. The hacker has all the time at his disposal and will regularly get better his skills, provoked by the millions of dollars in resolving risk. The paper is structured as follows: in Section 2 introduces the botnet forensic methodology and motivation, Section 3 brief summary of previous botnet forensic analysis. We propose a generic process model for botnet forensics analysis. Key Challenges are presented in Section 4, conclusion is given in Section 5.

2. BACKGROUND

Internet Relay Chat (IRC) is a text-based chatsystem that communicates bot in channels. They were capable to interpret simple commands, provide administration support, suggest simple games and regain information about operating systems, logins, email addresses, aliases, *etc.* [4]. Denial of service, then distributed

denial of service attacks were implemented in these IRC bots. They could proliferate like worms, remain hidden as viruses and could initiate huge, corresponding attacks like AgoBot and SDBot. The recent generation of bots can multiply through filesharing networks, peer-to-peer networks, email attachments and infected websites. Bots communication can be accomplished by several protocols, such as IRC, HTTP and P2P. Latest sophisticated botnet is CoolBot, which could explain the problems that how to recover shut down and accept delay problem of C&C and contradict against insecurity (routing table poisoning). CoolBot could control C&C model automatically and repair the broken C&C, which means C&C reconstruction [5].

2.1. Botnet forensic methodology

Botnet forensic methodology consists of three steps:

Malware collection

A 'Catch-it-as-you-can' system follows where all bots packets passing through an exacting traffic point are captured. Analysis is consequently done which require huge storage. A piece of bots packet is individually analyzed and stored in definite memory for future analysis [6].

Malware analysis

The botnet forensic system is a security device with hardware and pre-installed software. It is defined behavior-based analysis.

Botnet tracking

The extracted information from malware collection interferes into the control channel of the botnet network which tracks that what kinds of attack has occurred.

2.2. Motivation for botnet forensics Analysis

The defensive approaches of botnet forensics follows that prevention is better than attack, detection and response perspectives. Botnet forensics ensures that attacker spends more time and energy to cover his tracks for making the attack. Hackers/ criminals will be more careful to avoid prosecution for their prohibited events. This restriction reduces network crime rate and thus security improves. Internet Service Providers (ISPs) are also being made answerable for what's going on their network. Now a days companies doing business on Internet can not hide a security breach and are expected to prove the state of their security as a compliance measure for regulatory purposes.

3. BOTNET FORENSIC ANALYSIS

Various advanced botnet forensic concepts, designs and analysis approaches were planned to handle the botnet network environments. In recent years, a behavior-based bots detection tool has been developing fast, which gives a serious malware drive.

3.1. IRC traffic analysis

Mazzariello *et al.* [7] focused that how a mass of probably strong hosts can be control from being infected. IRC user behavior model organized in a channel to make difference between normal and botnet-related activity. They will concentrate on the problem of detecting botnets, by introducing network traffic analysis architecture, and describing a behavioral model, for a specific class of network users, able to identify botnet-related activities. Time analysis patterns of botnet activity and taxonomy both phenomenon are established through Botnet traffic analysis. This IRC traffic analysis is a versatile approach which based on systematic monitoring, for botnets detection which based on the network behavior. Initially analysis has been supervised then next testing of pure invalid anomaly was detected. Kugisaki *et al.* [8] studied on IRC behavior which directly related to an IRC server. This novel approach can be used to make judgments between of present bots more than existing viruses by computerization. More objects (problem of verification and generality of objecs), duration of detection by real visible and Measures against bots that does not use IRC.

3.2. Asprox botnet analysis

Borgaonkar *et al.* [9] studied the design and structure of the Asprox botnet, the communication protocols which drive-by downloading of spreading malicious substance and the advanced fast-flux service network. The main features of the Asprox botnet are the use of centralized command and control structure (C & C structure), HTTP based communication, advanced double fast-flux service networks, SQL injection attacks for recruiting new bots and social engineering tricks to spread malware binaries. Hydra fast-flux network, SQL injection attack tool is advanced features of Asprox. Asprox botnet does not suitable strong for Cryptography. In the botnet architecture, authenticity and integrity of the bot commands is important.

3.3. Cross-analysis of botnet victims

Balzarotti *et al.* [10] provide an in depth analysis passive (depend on human action or other) and active(bot frequently use network scanning techniques to get susceptible hosts for spreading infection) measurement study that how data get infected through major botnets like Conficker, MegaD, and Srizbi. They observed commonlymalware infected networks. IP address space and physical location of Conficker botnet can be observed by CAIDA. A Cross-botnet prediction technique is proposed to predict unknown victims of one botnet from the information of the other botnet if they have similar infection vectors. They will further provide new approaches to explain relationships between geopolitical locations and malware infection.

3.4. Financial botnet analysis

Financial botnets particularly aimed at carrying out financial fraud, popular threat for banking institutions. This is authenticated by one of the biggest savings banks in Spain which helps to fight against financial cybercrime. A financial botnet is identifying, analyzing, and mitigating through Financial Botnet Analysis. Banking Trojan is a representative malware which evaluated in financial institution. This analysis automatically emphasized on the detection, imagination and sharing intelligence about financial botnets [11].

3.5. Graph-based analysis

Nagaraja *et al.* [12] proposed Graph-based analysis, a powerful approach because it lacks protocol semantics or packet statistics dependence. It depends on being able to accurately model valid network growth. A botnet can be detected based on the observation that an attacker will increase the number of related graph components due to a rapid growth of edges between suspect neighboring nodes. BotGrep is a graph theory based approach to botnet detection and analysis. Nodes of communication graph represent Internet hosts and edges represent communication between them.

4. GENERIC PROCESS MODEL

We use a diagrammatic approach (Fig.1) for Botnet forensic analysis which is based on previous accessible forensics analysis.

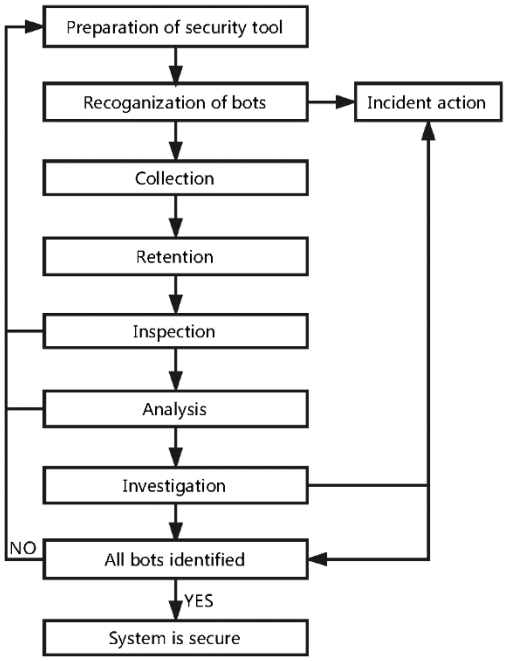

Fig 1. Generic Process model of Botnet Forensics Analysis

4.1. Preparation of security tool

Botnet forensics is relevant only to environments where bot security tools (sensors) like intrusion detection systems, packet analyzers, firewalls, traffic flow measurement software are installed. The required authorizations and legal warrants are obtained so that privacy is not dishonored. The preparation phase ensures the monitoring tools are in well place.

4.2. Recoganizations of bots

Various security tools produced a specific security infringe to indicate alert during unauthorized actions and inconsistency. Different parameters are used for the determination of presence and nature of the attack. An immediate validation is done to assess and confirm the suspected attack and ignore the false alert. TCPDump, Wireshark, PADS, Nepenthes, Snort etc. devices are used to confirm accurate alarm. Alert and collection of responses during attack is accomplished, bots are identified.

4.3. Incident Response

Crime response is convenient on the collected information which validates and assesses the event by organization strategy, authorized and business constraint. Securities against future attacks and recovers from the existing damage, preplanning is initiated. At the same time, the decision whether to continue the investigation and gather more information is also taken. A similar response is to be initiated after the investigation phase where the information obtained may requires certain actions to control and reduce the attack.

4.4. Collection

The traffic data is assembled from the botnet sensors and most of the facts causing minimum contact to the infected machine. Traffic data rapidly change and it is difficult to create the same trace later. TCPDump, Wireshark, Snort tools assist in collections of traffic data.

4.5. Retention

Traces of data and logs are stored on a backup device. The original security traffic data are unaffected for legal requirements. Single copy of the data will be analyzed. TCPDump, Wireshark, Snort tools is applied for retention phases.

4.6. Inspection

The whole traces data and specific evidences of the attack are composed of combined data format which can be analyzed. TCPDump, Wireshark, Flow-tools, NfDump, Bro, Snort tools provide a proper way to check each and every fact of the attack which improves the security tools.

4.7. Analysis

Previous botnet attack's pattern helps to classify the particular infection sign and reformed to understand the intention and methodology of the attacker and are classified and correlated. The data searching and matching attack patterns can be done by Statistical, soft computing and data mining. The tools which support in analysis of botnet attack are TCPDump, Wireshark, TCPFlow, TCPTrace, Olly Dbg, IDA Pro, NetFlow, TCPXtract, Snort *etc.*

4.8. Investigation

Botnet forensics is targeted to define communication pathway between an infected machine and back to the origin point of attack. Incident response and prosecution of the attacker is used to identify the attacker, the tough measurement of the botnet. IP spoofing and stepping stone attack is still prevalent technique of the attacker to hide himself.

4.9. Results (Max. Possibility of bot's identified)

The legal systematic format is designed to arrive at the conclusion. The botnet forensic analysis provides visual conclusion of the attacker methodology and feedback for future investigations to conduct the deployment and improvement of security products.

This generic process model of botnet forensics analysis is used in

both real-time and post attack scenarios [13]. The first five phases (including incident action) handle concurrent botnet traffic. The next four phases are common for real time and post attack scenarios. The post attack investigation begins at the inspection phase, where a copy of the packet capture (lib pcap format) file is given for investigation. The inspection phase fuses inputs from various sources and identifies attack indicators. The analysis phase classifies attack patterns using data mining and statistical approaches. The investigation phase involves trace back and attribution. Finally bot is captured, if results are not satisfactory for further improvement of the security tools.

5. RESEARCH CHALLENGES

5.1 Collection and Detection

The main problem is that different kinds of bots having their different characterization makes it very tough to detect these bots, to define the logical relationship between different bots, arises the new challenges to the accuracy of population counting techniques. Botnet Overlapping between botnet counting and detection creates potential hidden relationships among botnets.

5.2. Botnet Size

Each and every minute new advanced bots (TDL-4, Grum) are generated in the internet field and its very tough to guess the kind of next bot's attack and how powerful it will be. Botnet forensic analysis involves capturing of bots and tells, what is the position of attack with its maximum possible botnet size. Waledac Botnet size estimation is difficult because botnet itself was capable of sending about 1.5 billion spam messages a day, or about 1% of the total global spam volume. It will be difficult to operate on a new botnet especially on the encrypted botnet.

5.3. Botnet traffic filter

It does not contribute to any information between Failover pairs. Failovers or Reboots requires redownload of the Dynamic Database. Currently there is no support for IPV6.

5.4. Investigation

It is biggest challenge to investigate a robust botnet unwanted traffic detection algorithms and how to filter botnet command and control (C&C) traffic early.

5.5. Analysis

Active analysis is required because honeypot setup is difficult on large scale network. Passive anomaly analysis usually independent of the traffic content and has the potential to find different types of botnets (e.g., HTTP, IRC and P2P).

5.6. Temporal correlation technique

This technique utilize between DNS queries and entropy based correlation between domain names, for speedier detection. It is difficult to applied a more system level logs such as Process/service executions, memory/CPU utilization, disk reads/writes. It is a biggest challenges server failure based DNS failures, or failures related to the name servers, as a means for detecting botnets which exhibit double fast flux.

6. CONCLUSION

Botnet forensics analysis is helps to capture, detect and trace particular bot among piles of bots. It also defines the possible complicated relationship between different kind of bots and tracing the source of attack with hackers. It provides a systematic pathway to predict future attacks by using intrusion data of previous botnet attack strategy.

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Forensic Accounting on Corporate Governance Maturity mediated by Internal Audit: A Conceptual Overview

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ABSTRACT Identification and development of forensic accounting as an organization's essential intangible asset has been traced as an immense vital essence that can influence corporate governance maturity. This paper attempts to integrate relevant empirical research and literature to extend the intended potentials of forensic accounting on corporate governance maturity particularly in public listed companies in Oman. Moreover, this paper will identify the role of forensic accounting as preventive measure rather than a detective control which is at present widely understood. The paper also proposes that internal audit poses a mediating role between forensic accounting and corporate governance maturity by linking professional theory and agency theory in its relationship. Since the existing literature provides less evidence that attempt to observe the influence of forensic accounting on corporate governance maturity, this paper offers and calls a promising proposition for future research.

KEY WORDS Forensic Accounting, Corporate Governance Maturity, Auditors, Fraud, Forensic science

1. INTRODUCTION

It is widely understood and as mentioned by many scholars that poor corporate governance leads to fraud, misappropriation of assets and dissatisfied shareholders [1]. It is also stated by [2], that no country is invulnerable to fraud. History and recent past is filled with events where organizations demonstrated poor corporate governance and end up either in filing bankruptcy or incorporate huge losses in their financial statements (Vinita, 2005).

Vinita [3] and Fernando [4] stated that recent frauds are not only due to the failure of corporate governance but also demonstrated poor accounting practices which were not detected by the conventional auditors. Controlling ownership and minority shareholders protection is difficult through conventional corporate control mechanism, *i.e.*, it requires process enhancement which can be provided by Forensic accounting [5]. Besides, auditors have denied the role for identifying fraud which had created an expectation gap between shareholders and auditors [6]. This expectation gap can only be filled with Forensic Accounting. The similar concept is defined by The Association of Certified Fraud Examiner [7], that financial statement auditors' (*i.e.*, external auditors) are not fraud examiner and also states that, external auditors cannot be considered as the most efficient way to detect or limit fraud.

According to [7] firm and durable corporate governance practices are necessary when owners (shareholders) are not responsible for setting strategy or carrying out business activities, for example publicly traded companies. These corporate governance practices or codes assist preventing fraud and fraudulent activities. These codes can be further strengthened by utilization of the right anti-fraud expertise *i.e.*, Forensic Accounting. Furthermore, [3] stated that aftermath of corporate accounting scandals and the resultant outcry for transparency and reliability in reporting created two outcomes. First is "forensic accounting" and second is "innovation in corporate governance".

Bhasin [8] stated that fraud exists in our society for centuries long. It is estimated that the typical business loses 5 percent of its revenues each year to fraud, this equates to $50,000 for every $1 million in annual revenues [7]. Such a disastrous situation requires certain additional steps and one of which is acquiring the assistance of Forensic Accounting towards enhancing and strengthening corporate governance. In accordance with [9] Forensic Accounting should be seen as the application of financial skills and investigative mindset conducted with the context to resolve

unresolved issues, thus complementing corporate governance in a manner which is not covered by the management's regular devised controls.

1.1. Background of the Study

People respond to what is inspected, not what is expected [10]. Several mitigating factors should be available within an organization for the entire internal deficiencies. Such internal mitigating factor reduces the time delay for solutions, prevents additional value loss and multiplies the number of tools available for implementation of solutions. It is widely understood that corporate governance is an internal process and majorly persuaded and prompted internally. If internal controls are not strengthened by the use of expertise, then corporate governance is bound to collapse, corporate governance maturity (CGM) will be impossible to achieve and above all, it will also raise the ventures for fraud and embezzlement.

Gee [11] opined that ever changing time requires the new technologies and expertise as the criminals are always one step ahead in thinking and executing the crime. In these regards, the conventional way of fighting or eliminating fraud requires change as well. This change can be defined as Forensic Accounting which is also the necessity and should be considered as an essential requirement for the implementation of good governance and eventually lead towards attainment of CGM. As mentioned by [12] and [13], some tools which were utilized in detecting the fraud were provided and operated by Forensic Accounting which resulted in formation of many governance committees *e.g.*, Committee of Sponsoring Organizations of the Treadway Commission (COSO) and Sarbanes-Oxley Act (SOX).

Forensic Accounting requires providing services which are beyond the general understanding of corporate people. As mentioned by Center for Forensic Studies, it is expected from Forensic Accounting to offer reliefs to shareholders by assisting the conventional auditors. Moreover, injecting Forensic Accounting techniques into conventional auditing will be effective to prevent leakages caused by corporate failure, *i.e.*, provide preventive measures to the organization.

1.2. Research Gap

Several studies are available which define Forensic Accounting as an institution or person who appears or calls upon after the fact (*i.e.* when the fraud has actually happened). For instance, [6, 11, 14-16] investigated the role of Forensic Accounting as detection control, litigation expert, and fraud finder.

There are only a few studies available which stressed that Forensic Accounting should be a part of corporate governance. However, there is no study that demonstrates the relationship of Forensic Accounting as a governance management system and as part of organization's management team. In accordance with [17] governance management are those which are directly responsible for the governance of organization, *i.e.*, board of directors, audit and risk committee, governance and compliance committee and internal audit department. On the other hand, [1] and [18], stated that Forensic Accounting is positioned to explore the redesign of corporate governance because of its skills and knowledge. Here the question arises if Forensic Accounting is positioned to redesign corporate governance then why Forensic Accounting cannot become a function of governance management?

Furthermore, there are no specific standards available for Forensic Accounting like Internal and External Auditing. In the absence of these standards, Forensic Accounting as profession is considered as part of audit instead of being considered as a separate standalone body with own standards and practices. Both Institute of Internal Auditors [19] and American Institute of Certified Public Accountants [20] negated the role of identifying the fraud and labeled it as management's responsibility and this role of external auditors as mentioned in [20], is acceptable to Securities and Exchange Commission of United States [2, 21].

Further to above, there is no doubt and in accordance with regulatory standards, it is the management's responsibility to identify and report fraud. However, in doing so management requires expertise; which is Forensic Accounting. Even though Forensic Accounting is becoming a necessary part of any organization, it is still not visible within the Codes of Corporate Governance issued by many authorities and regulators including the recent code issued in Oman [22].

Furthermore, the researcher is not able to find specific role of Forensic Accounting towards:

- Supporting organization’s operations as risk and fraud compliance testing function.
- Achieving CGM as policy developer, risk assessor, and fraud testing function.

Since the existing literature provides less evidence that attempt to observe the influence of forensic accounting on corporate governance maturity, this paper offers and calls a promising proposition for future research.

The interests of investors and other stakeholders are usually protected by a three-tier security system which comprises of governance codes, second is organization's management and last are the controllers such as auditors [23]. These three tiers lead to one another for the achievement of CGM and on the whole becomes overall process of CGM. If any one of the three tiers are not performing effectively and efficiently, then the whole process could collapse [24]. In accordance with [3], organizations fail to achieve corporate governance and eventually CGM due to following reasons:

- Lack of well formulated and implemented policies and standards of achieving CGM.
- Lack of honesty, integrity and transparency in financial reporting
- Inefficient and ineffective system of risk assessment

In accordance with the research gap and problems discussed above, the proposed research questions are: Is there any association

between FA and CGM? Is there any relationship between FA and internal auditors? Is there any correlation between internal auditors and CGM? Whether internal audit mediates relationship between Forensic Accounting and CGM?

2. LITERATURE REVIEW AND THEORETICAL BACKGROUND

This section will focus on the existing literature relevant to this paper. Review of existing studies will provide strong foundation for understanding that why FA is necessary, how it can strengthen CGM and how internal audit can perform as mediator between FA and CGM? This section will also discuss the theories which support the issues related to enhancement of CGM through Forensic Accounting and internal audit as mediator.

2.1. Past Studies on CGM

Given the ever-growing concerns of various stakeholders, corporate governance has transformed from just being a buzz word to a dependable and substantial method to ensure preservation of shareholder's value. In this regard, CGM evolved into an industry's skeptical framework which the key attributes associated with levels of maturity on the continuum to becoming a better governed organization [24].

There are certain fundamental requirements which are very essential towards CGM. These requirements include legal compliance, accountability, effectiveness, and efficiency of operations and ethical behavior [25]. In accordance with [26], it is the responsibility of senior management and board of directors to act towards achievement of CGM. Board of directors and senior management should act as the focal and central point and also act as the custodians of corporate governance.

Corporate governance itself cannot achieve anything unless certain measuring tools are incorporated to assess its performance and its impact on organization. As mentioned by [27] corporate governance can be tick box compliance or can be properly implemented to achieve business goals. To measure the corporate governance, CGM models are utilized which defines whether organizational governance is heading towards accomplishment of goals or not. In accordance with [24] CGM can assist organizations to identify where corporate governance competencies may be positioned on a maturity range and what are the gaps that exist between actual and planned performance.

CGM is difficult to achieve where there are complex corporate relationships, weak regulatory requirements, weak legal and judiciary system and scarce human resource capabilities [4]. But if it is implemented, controlled and achieved then CGM can ensure developed markets, sound policies and procedures and system of reward and accountability. Assurance is required towards implementation and achievement, whereas elimination of fraud is required for proper control and safeguarding organization's repute. These assurances and eliminations cannot be achieved without IA and assistance of FA [25, 28].

CGM is the first step towards understanding where the organization stands regarding corporate governance. The big question here is to identify whether the governance can be measured or not? As stated by [29], the fact that corporate governance encompasses many different kinds of aspects, both 'hard' and 'soft', indicates that perhaps some of them can be measured more easily than the others. In accordance with [30] and [31], since hard aspects coincide largely with aspects of compliance, there may well be a possibility to measure this compliance, whereas, so-called 'soft' aspects (beyond the numbers), which are to be situated largely in the 'control environment', the question is not so easily answered.

There are several tools available for the measurement of governance maturity provided by [24, 32-34] moreover and as mentioned by [31] any tool which best serves the organizational requirements can be utilized. In governance risk and compliance capability module defined by [35] there are eight elements that need to be measured and this includes principles and critical success factors. If CGM elements are measured properly and deployed effectively, they will result in the following universal outcomes:

- Achieve business objectives.
- Enhance organizational culture.
- Increase stakeholder confidence.
- Prepare and protect organization.
- Prevent, detect, and reduce adversity and weakness.
- Motivate and inspire desired conduct.
- Improve responsiveness and efficiency.
- Optimize social and economic value.

All above outcomes cannot be achieved unless element of fraud is eliminated. For this reason, Forensic Accounting plays a major role in the direction of assessment and achievement of CGM. Moreover, and in accordance with [26] internal audit is one of the key role players towards the achievement of CGM. It is adequate to mention that CGM is completely dependable on various components, rules, and regulations. From these components, Forensic Accounting and internal audit is one of the crucial and vital functions [4, 8, 36].

Corporate governance is a system, which provides the platform for organizations to perform in a way which is beneficial to all stakeholders. History is filled with events, where organizations collapse because of poor or non- availability of corporate governance. Poor corporate governance is referred to a term where corporate governance is present but it's not implemented in a manner which can ensure the achievement of organizational goals, *i.e.* if it is only utilized as compliance check box. Achievement of CGM in the modern financial and business era is not an extra or choose-able option. CGM is fundamental and primary tool towards raising capital, satisfying shareholders and running business successfully. CGM is essential to all stakeholders including employees, vendors, customers, and bankers. CGM also reduces

ambiguity and reassures accountability by encouraging adoption of IA and FA in its system.

2.2. Past Studies on Forensic Accounting (FA)

Forensic Accounting is need of an hour and is also essential pillar for all organizations [21]. FA is mainly recognized for detecting financial frauds and for this reason, any study of Forensic Accounting is coarse unless it is combined with fraud and tackling of fraud [37]. Bhasin [38] opined that, FA came into existence because of the continuous and rigorous frauds, which are not detectable by the common auditing tools, additionally, conventional way of auditing is not enough as frauds are still transpiring, despite of the presence of policies, governance codes and governance bodies.

FA is defined by many scholars as integration and amalgamation of auditing, investigative and accounting skills. Eliezer and Emmanuel [39] explained that specialized area within accounting profession is known as Forensic Accounting. Forensic Accounting engagements can be suitable for actual or anticipated quarrels or lawsuits. Forensic means "suitable for use in court of law" Mitrić, Stanković, and Lakićević [40] established that segment which deals with the study of fraud and malfeasance is called Forensic Accounting and person who performs Forensic Accounting is called forensic accountant. The comprehensive definition is defined by [41]:

"...a multidisciplinary field that encourages both a profession and an industry, where civil or criminal economic and financial claims, whether business or personal, are contested within established political structures, recognized and accepted social parameters, and well-defined legal jurisdictions, and informed by the theories, methods and procedures from the field of law, auditing, accounting, finance, economics, psychology, sociology, and criminology"

It is necessary to explain here that there is a difference between forensic accountants, fraud auditors, and financial auditors. According to [21] financial auditors are only concerned with the compliance with applicable standards and laws; fraud auditors identify the potential fraud and raise the red flag whereas Forensic Accountants check every area of the potential fraud, identify the reasons, amount, perpetrator and also suggest the way forward and lesson learned.

FA arises from the cause and effect of fraud and technical error made by human [14]. Likewise, and as mentioned by [42] the outbreak of occupational fraud and financial abuse has increased pressure on the accounting and or auditing professions to find improved ways of uncovering financial crimes and the answer for such problem is FA [38].

As described by [21] the term forensic accounting refers to the comprehensive view of fraud investigation. It includes preventive measures related to frauds and analyzing anti-fraud controls which are present in organization's system. Enofe, Ekpulu, and Ajala [43] opined that FA could directly influence corporate governance. Similar explanation is defined by [2] that FA can positively impact organizational achievement of goals by eliminating fraud risk and strengthening internal controls. Therefore, it can be asserted that FA plays major role in strengthening corporate governance and achievement of CGM.

Although FA is operating without any regulating standards but its characteristics and skills makes this activity valued and appreciated. Imoniana, Antunes, and Formigoni [44] define skills of FA as comprehensive and enough to impact the achievement of CGM. Moreover, [1, 18] stated that Forensic Accounting is positioned to explore the redesign of corporate governance because of its skills and knowledge.

In accordance with [7], the majority of the frauds occur in the category of asset misappropriation, however, they are the lowest in the monetary loss, whereas financial statement fraud is the lowest in frequency, yet it is highest in the median loss. It is worth mentioning that asset misappropriation is controlled and monitored by internal and external auditors, but for detection and prevention of financial statement fraud, FA is required. One of the distinctive features of corporate governance is to present true and fair view of the financial statements and if importance is not given in the area of financial statement fraud, then the survival of corporate governance can be jeopardized or will be at high risk.

In accordance with [14, 16, 21, 45], FA is only invited once the fraud is detected. This paper intends to enhance value of FA as part of governance management where fraud can be prevented before it occurs and FA can further strengthen the internal audit department and also audit committee in order to achieve CGM. A similar concept is mentioned by [2], stating that FA with appropriate education, training, and experience can provide assistance to departments and governance bodies to enhance their functions and responsibilities towards fraud detection and prevention.

In current business environment fraud testing is becoming a requirement. It is an obligation of organization to provide assurance to shareholders and its management that organization's financial statements and operations are free from fraud and FA is the paramount option in providing such assurance. Although there are no standards or regulations for FA, but ever-changing business environment created the need for this profession.

FA can be considered as competent specialist to influence IA, especially in case where auditors denied the fact of identifying fraud. FA can be an important aspect of any organization which can assist in achieving CGM and develops effective mitigating controls. Moreover, FA role is not utilized up to its full potential and is only utilized when fraud occurs *i.e.*, as detective control instead of preventive measure.

2.3. Internal Audit as Mediator

In order to achieve CGM, organizations' boards of directors are asserted with responsibility towards maintaining effectiveness of internal control systems. In this case, the internal audit plays vital role in assisting the board to discharge its governance

responsibilities [17, 46]. Furthermore, and in accordance with [47], it is the duty of IA to provide assurance for the effectiveness of organizational operations and governance. In these regards, IA becomes an integral part of corporate governance and also vital tool towards the achievement of CGM.

As mentioned earlier, IA is governed by standards and frameworks. These standards are defined by Institute of Internal Auditors (IIA). In accordance with IIA internal audit is:

"…Independent, objective assurance and consulting activity designed to add value and improve an organization's operations. It helps an organization accomplish its objectives by bringing a systematic, disciplined approach to evaluate and improve the effectiveness of risk management, control, and governance processes."

Further to above, management is responsible for controlling risk to ensure that the objectives are met while the scope of internal audit is based on reviewing risk management and internal controls [48].

The major task of IA is to provide assurance [28]. These assurances are directed towards governance, risk and internal controls. Furthermore, and in accordance with [25, 49], stakeholder expectations related to the roles of IA in assessing and making assurance on governance maturity have increased and IA plays significant role in supporting, planning, assessing, and enhancing CGM. This makes IA an integral part towards providing assurance for CGM and clearly demonstrates that IA has direct relationship with CGM.

Responsibility for CGM falls on an organization's board of directors and its audit committee. IA endorses corporate governance by serving as a resource to the board and the audit committee by providing assurance on control testing, advisory, and organization insight [50]. Similarly, and in accordance with [36] IA role in risk management is very crucial but internal audit is either not ready to pursue or is not proactive in pursuing it. However, with the right level of skills and experience, IA will be able to carry out this role very effectively.

Further to above, for the fraud risk, it is opined by [19] that internal auditors must have sufficient knowledge to evaluate the risk of fraud but are not anticipated to have skills and expertise of a person whose primary responsibility is detecting and investigating fraud. It is worth mentioning that this expertise and knowledge can be provided by FA. Likewise, inclusion of FA into IA will not only strengthen the CGM but will also complete the IA's process related to risk evaluation, control testing, and auditing procedures.

IA is a key element of the corporate governance structure, contributing to the overall quality of the control environment and internal controls [17]. In current business environment, IA is compulsory CGM component and plays important role in strengthening organizational controls. However major suffering of organizations is due to fraud which is lacking in IA's role. By utilizing FA, fraud risk aspect will be dealt with specialized approach and will also complete the control cycle.

3. UNDERLYING THEORIES

In accordance with [51] theories are formulated to explain, predict and understand facts/ events. There are several theories available for corporate governance; however, there are only a few available in the field of Forensic Accounting and internal audit which can directly attribute to this paper. For the purpose of this paper following theories are utilized:

1. Agency Theory
2. Theory of Profession

There are possibilities of other theories to be included in future research; however, directly linked theories are those which are mentioned above. Brief of these theories are mentioned below:

3.1. Agency Theory

Agency theory can be defined as shareholders delegate some responsibilities to a team of experts while keeping in mind that they will perform best for the success of their organizations [52]. It is worth mentioning, that success cannot be achieved without attaining CGM. Similar concept is explained by [53] that an agent or agency is hired by one or more person(s), called the principal(s), under a contract and is compensated by the principal to achieve desired outcomes for the principal. Because the agent is acting on behalf of the principal, the principal gives away decision-making authority to the agent. Furthermore, and in accordance with [4, 54] agency theory is applied to explain dominant role of agents on corporate governance.

Hired agents are directly responsible for the implementation of corporate governance and achievement of CGM. This clearly demonstrates that corporate governance is entirely dependent upon the agents which are hired by principals. These agents form different committees among themselves to further distribute responsibilities such as board of directors, audit committee and risk committee. In accordance with [55], internal audit directly reports to audit committee and plays vital role concerning organizations governance maturity.

Agency theory defines the relationship between management, shareholders and shareholders' nominated directors. Management is responsible for the delivery of results and safeguarding the interest of shareholders and this interest can only be protected by achieving CGM and utilization of control tools which can be categorized as internal audit and FA.

The focus of corporate governance is security of interest towards stakeholders with specific focus on shareholders. As mentioned by [52] delegation, as per agency theory, creates problems when managers neglect the concerns of their principals (shareholders) and put their self-interests on priority line and start gathering private benefits. In accordance with [14] common mind set behind gathering private benefits is that the agents perform entire task and do not want to provide benefits to shareholders who only invest money and perform no operations. Such kind of behavior requires

protection and monitoring which can certainly be provided by FA and IA.

3.2. Theory of Profession

Forensic Accounting is a profession and many specialists in other fields are seeking to become professionals in this field [13]. This theory defines how profession should work and what are its peculiarities and attributes. The theory of profession can also be defined as the authority and repute provided by the general public and associations to the profession for protecting public interest. As mentioned by [56], this theory provides an Analytical comprehension which assists in understanding the characteristics, attributes, and structure of the forensic accounting profession.

Above mentioned attributes are utilized to assess the profession of FA, their skills and competence. Assessment is made relating to providing assurance services for stakeholders specially organization's management and shareholders. Although there are no official codes available for Forensic Accounting, however, codes utilized by Chartered Accountants and Certified Internal Auditors can be applicable to profession of FA. Likewise, and as informed by [4], that it is essential to employ, train and reward professional managers who can be held to high standards of competency, ethics and responsibility and thus assists in achieving and maintaining CGM.

Internal audit is already well versed in their profession and recognized as major tool in relation to CGM however; if FA is included in internal audit profession then internal audit along with FA will become robust, efficient and effective defense control for the achievement of CGM.

Theories assist in defining conceptual framework and also aiding variables of this paper. Agency theory defines the relationship among principals and agents, additionally, this theory also emphasizes the protection of principal's rights. This protection can be achieved by introducing FA and internal audit which in turns enhances corporate governance and eventually pave the path for achieving CGM. Theory of profession force FA and IA to perform their task in a manner which can assist in protection of public interest.

4. PROPOSITION DEVELOPMENT

After tendering above arguments on FA and IA, it is indeed interesting to further explore the contributions of FA on CGM of public listed companies in Oman. The aim of this proposed research is twofold. It is an ultimate aim that this research should see whether FA improve CGM and also if IA brings positive synergy on the relationship between FA and CGM of public listed companies. If the outcome shows a positive and effective role on an organizational success, then these companies should seriously start considering and adopting a method to identify, manage, measure and utilize FA and IA to its optimum.

A. Forensic Accounting and Corporate Governance Maturity

FA, if utilized to its full potential, can assist organizations in achievement of CGM [38]. According to [7, 21, 57], fraud risk is the highest among all risks which adversely impacts organization's ability to achieve CGM and in accordance with [2], FA is best positioned to stamp out the fraud risk.

As mentioned by [52], agency theory defines the concerned and interrelated parties in corporate governance, whereas, theory of profession as mentioned by [58] emphasizes on Analytical comprehension; which assists in understanding the characteristics, attributes and structure of the FA profession. Likewise, theory of profession also emphasizes on maintaining highest ethical standards, professionalism and protection of public interest, therefore, FA can be an agent as mentioned in agency theory and can positively influence corporate governance in achieving CGM.

In accordance with the above, researcher will develop the first proposition:

Proposition 1: Forensic Accounting has a positive association with corporate governance maturity.

B. Forensic Accounting and Internal Audit

As per [19] and for the adoption of theory of profession, internal audit itself cannot achieve the purpose of this theory, unless, it is equipped with FA techniques and practices. In order to prevent rights of the principals, agency theory and for the purpose of professionalism as mentioned in theory of profession internal audit requires integration with FA. Furthermore, and in accordance with [43, 59], Forensic Accounting can influence the decision, working and opinion of auditors. These influences can range from establishing need or requirement for fraud testing and investigation, verification of existence or in-existence of fraud and fraud risk compliance adherence.

Based on the above, second proposition would be as follows:

Proposition 2: Forensic Accounting has a positive influence on auditors' opinion.

C. Internal Audit and Corporate Governance Maturity

Board of directors and audit committee are the integral part of agency theory [4]. They are also responsible for promoting effective corporate governance system and internal audit function plays a key role in assisting the board and audit committee to discharge their governance responsibilities for the achievement of CGM [46].

As opined by [52, 59], agency theory defines concerned and interrelated parties in corporate governance and it also defines the necessity of internal audit as part of governance management. In addition, and according to the theory of profession internal audit is required to follow its standards which evidently ensure achievement of CGM [25].

Based on the above, the third proposition would be:

Proposition 3: Internal audit has a positive relationship with CGM

D. Mediating Proposition

Mediator or an intervening variable is a type of variable which

describes the relationship between an independent and dependent variable [60, 61]. Effective and efficient internal audit is undeniably crucial to guarantee CGM and reliable financial reporting that eventually boost the investor's confidence in the capital markets [17, 54]. As per the Agency theory, CGM cannot be achieved unless all of its constituents are functioning effectively and efficiently *i.e.* CGM is dependent on other variables' performance and success.

In line with [62], theory of profession defines that the auditor is responsible for identifying fraud and its related components whereas in accordance with [19] IA requires assistance and expertise of a person who is expert in fraud detection *i.e.* Forensic Accounting. Thus, it could be essential that internal auditor obtains expertise from Forensic Accounting and provides its opinion with prudence which enhances the likelihoods of accomplishing CGM. Therefore, it could be stated that internal audit plays mediator role between Forensic Accounting and CGM.

In similarity to mediating relationship defined by [2] and stated above in proposition 1, 2 and 3, there is positive significant direct relationship between FA and CGM, a positive significant direct link between FA and IA, and a positive significant direct relationship between IA and CGM. For this reason, this study can affirm that IA mediates the relationship between FA and CGM.

From the above-mentioned theories, the fourth proposition would be:

Proposition 4: IA plays mediating role in the relationship between FA and CGM

5. CONCEPTUAL FRAMEWORK

The proposed mediation model is illustrated in Figure 1 below. The model proposes that the independent variable (FA) influences the mediator (IA), which then will influence the dependent variable (CGM). As opined by [63], IA can be examined through its responsibility to ensure business transparency, examining and monitoring effectiveness of internal control and maintain high integrity in their corporate business activities and operations.

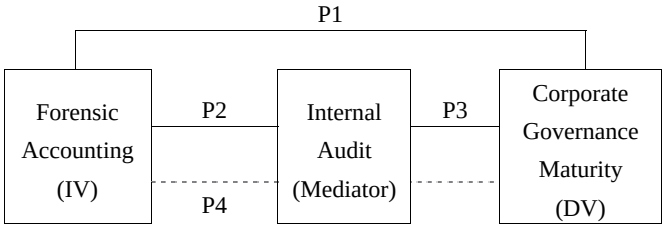

Fig. 1. Conceptual Framework

FA is proposed as the independent variable based on the fact of literature and previous research, which reveals that FA can have strong influence on CGM [1, 18]. Simultaneously, past research also suggests that FA and IA are interrelated [19, 43, 59]. As mentioned by [64] agency theory suggests a series of procedures to reconcile interest of shareholders and managers. These procedures include monitoring agent's behavior by implementing auditing and other governance instruments; thus it can be substantiated that CGM is dependent variable which can be influenced by IA and FA.

6. CONCLUSION

The intention of this study will be to explore potentials to examine the mediating effect of internal audit on FA and CGM as shown in proposed conceptual framework. The issue of corporate frauds, fraud detecting methods, and corporate governance failure is frequently highlighted in several literature. Most literature found is towards addressing the issues on FA skills, FA traits, fraud detection techniques, managing corporate governance, and also on FA and CG definitions. However, researcher was not able to find particular attempt to investigate FA as preventive measure for CGM with IA as mediator hence making this paper's propositions unique.

Distinctive role of FA is expected to set immense influence on achieving CGM. Hence, this is an indication that FA must be deployed in a manner to ensure that its properties are identified and optimized to achieve business goals and improve CGM. FA alongside with IA and with its own innovativeness, creativity, skills, and knowledge provides potential for excellent operational system, well controlled policies and eventually would result into a positive impact on profitability, business sustainability, and integrity.

Why investigate mediating role? It is mainly because there is great possibility that the relationship between FA and CGM is not exclusively direct. Conceptually, Internal Audit is a process by which an organization secures assurance that the risk exposures it could face is understood and managed appropriately. Moreover, and in the absence of specific standards, it is believed that the effectiveness of FA and its utilization is driven by the effectiveness of internal audit function.

Notably, this paper positions itself in extending previous studies on FA to a new perspective by incorporating its preventive role towards strengthening corporate governance maturity. This is expected to contribute and bring new insights and views on FA which have not been explored before. This should offer vast opportunities for future researchers to investigate further via diverse perspective pertaining to FA. Furthermore, this paper expects that the proposed theoretical framework developed will be extended to an empirical phase following this paper.

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Two Different Approaches to Handle Landmark Location Uncertainty in Skull-face Overlay: Coevolution vs Fuzzy Landmarks

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ABSTRACT Craniofacial superimposition is a forensic process where photographs or video shots of a missing person are compared with the skull that is found. By projecting both photographs on top of each other (or, even better, matching a scanned three-dimensional skull model against the face photo/video shot), the forensic anthropologist can try to establish whether that is the same person. The whole process is influenced by inherent uncertainty mainly because two objects of different nature (a skull and a face) are involved. In this paper, we propose a novel approach, a cooperative coevolutionary algorithm, to deal with the use of imprecise cephalometric landmarks in the skull-face overlay process. Following this approach, we are able to look for both the best transformation parameters and the best landmark locations at the same time. Coevolutionary skull-face overlay results are compared with our previous fuzzy-evolutionary automatic method over six skull-face overlay problem instances corresponding to three real-world cases solved by the Physical Anthropology lab at the University of Granada (Spain). Promising results have been achieved though the robustness of the method should be improved.

KEY WORDS Forensic identification, Craniofacial superimposition, Skull-face overlay, Coevolution, Cooperative coevolutionary algorithm, Fuzzy landmarks, Evolutionary algorithms, Forensic science

1. INTRODUCTION

Craniofacial superimposition (CS) [1, 2, 3] is a forensic process where photographs or video shots of a missing person are compared with the skull that is found. By projecting both photographs on top of each other (or, even better, matching a scanned three-dimensional skull model against the face photo/series of video shots), the forensic anthropologist can try to establish whether that is the same person. This skull-face overlay (SFO) process is usually done by bringing to match some corresponding anthropometrical landmarks on the skull and the face.

SFO is known to be one of the most time-consuming tasks for the forensic experts [4] (it takes up to 24 hours in many real-world situations).

As it is explained in [5], we have developed an automatic method that overlays a 3D model of the skull over a 2D photograph of the face of the missing person. With that aim, we studied and experimented with different evolutionary approaches in [5], where CMA-ES demonstrated to be the most accurate and robust approach.

The SFO process is influenced by inherent uncertainty since two objects of different nature are involved (a skull and a face) [6]. In [7] we studied in detail the sources of uncertainty related to the SFO task and proposed the use of imprecise landmarks to overcome most of the limitations associated with them. Using imprecise landmarks, forensic anthropologists are able to properly deal with two different problems. On the one hand, the difficult task of locating anthropometric landmarks invariantly. On the other hand, the identification of a big enough set of non-coplanar landmarks. These imprecise landmarks were modeled following the fuzzy set theory-based approach and their use led to a really important performance improvement of our automatic method.

However, the fuzzy-evolutionary approach relies on more computational operations due to the fact that distances between a crisp point and a fuzzy set of points must be computed. Hence, the run time required by the algorithm increased. In particular, the crisp landmark approach ranged in 10-20 seconds per run while the

fuzzy landmark approach ranged in 2-4 minutes.

With the aim of decreasing the run time needed without losing accuracy, we propose a new evolutionary approach based on a coevolutionary algorithm (CEA) [8]. It also takes advantage of imprecise landmarks but, unlike the fuzzy approach where distances between a fuzzy set and a crisp point have to be calculated (computationally costly), it only needs to calculate Euclidean distances between pairs of crisp points.

The novel proposal is tested on six SFO problem instances derived from three real-world identification cases solved by the Physical Anthropology Lab at the University of Granada (Spain).

The structure of the paper is as follows. In Section 2 we describe the SFO problem and our previous evolutionary method to deal with it. Then, we study the sources of uncertainty associated with the SFO task (Section 3) and summarize our previous fuzzy approach to tackle them. Section 4 is devoted to introduce our proposal based on a cooperative coevolutionary algorithm. In Section 5, we test and compare the new proposal against the fuzzy-evolutionary one over six problem instances. Finally, we present some concluding remarks and future works in Section 6.

2. SKULL-FACE OVERLAY IN CRANIOFACIAL SUPERIMPOSITION

The success of the SFO process requires positioning the skull in the same pose of the face as seen in the given photograph (provided by the relatives of the missing/deceased person). The orientation process is a very challenging and time-consuming part of the CS technique [4].

Most of the existing SFO methods are guided by a number of anthropometrical landmarks located in both the skull and the photograph of the missing person. The selected landmarks are placed in those parts where the thickness of the soft tissue is low. The goal is to ease their location when the anthropologist must deal with changes in age, weight, and facial expressions.

Once these landmarks are available, the SFO procedure is based on searching for the skull orientation leading to the best matching of the two sets of landmarks.

In view of the task to be performed, the relation of the desired procedure with the image registration (IR) problem in computer vision [9] can be clearly identified. Following a 3D-2D IR approach we aim to properly align the 3D skull model and the 2D face photograph in a common coordinate frame. The required perspective transformation to be applied on the skull was modeled in [5] as a set of geometric operations involving twelve parameters/unknowns which are encoded in a real-coded vector to represent a superimposition solution.

Formally, SFO can be formulated as follows: given two sets of 2D facial and 3D cranial landmarks, $\boldsymbol{F}$ and $\boldsymbol{C}$, respectively, both comprising N landmarks:

$$F = \begin{bmatrix} x_{f_1} & y_{f_1} & 1 & 1 \\ x_{f_2} & y_{f_2} & 1 & 1 \\ \vdots & \vdots & \vdots & \vdots \\ x_{f_N} & y_{f_N} & 1 & 1 \end{bmatrix} C = \begin{bmatrix} x_{c_1} & y_{c_1} & z_{c_1} & 1 \\ x_{c_2} & y_{c_2} & z_{c_2} & 1 \\ \vdots & \vdots & \vdots & \vdots \\ x_{c_N} & y_{c_N} & z_{c_N} & 1 \end{bmatrix}$$

the overlay procedure aims to solve a system of equations with the following twelve unknowns: a rotation represented by an axis (d_x, d_y, d_z) and angle (θ), a center of mass (r_x, r_y, r_z), a translation vector (t_x, t_y, t_z), a uniform scaling (s), and a 3D-2D projection function given by a field of view (ϕ). The corresponding equation system is as follows:

$$F = f(C) = C \cdot (A \cdot D_1 \cdot D_2 \cdot R_\theta \cdot D_2^{-1} \cdot D_1^{-1} \cdot A^{-1}) \cdot S \cdot T \cdot P \quad (1)$$

where $R = (A \cdot D_1 \cdot D_2 \cdot R_\theta \cdot D_2^{-1} \cdot D_1^{-1} \cdot A^{-1})$ represents a rotation matrix to orient the skull in the same pose of the photograph. S, T, and P are uniform scaling, translation, and perspective projection matrices, respectively. The interested reader is referred to [10] for a detailed description of the matrices in Equation 1 and their relation with the twelve unknowns of the problem, as well as to [5] for a deeper explanation.

Different definitions of the fitness function were studied and the one achieving the best results was the mean error (ME)[1]:

$$ME = \frac{\sum_{i=1}^{N} \left\| f(cl^i) - fl^i \right\|}{N} \quad (2)$$

where $\| \cdot \|$ is the 2D Euclidean distance, N is the number of considered landmarks (provided by the forensic experts), cl^i corresponds to every 3D craniometric landmark, fl^i refers to every 2D facial landmark, f is the function which defines the geometric 3D-2D projective transformation, and $f(cl^i)$ represents the projected skull 3D landmark cl^i in the image/photo plane.

Solving the SFO problem in the latter fashion results in a really complex optimization task, with a highly multimodal landscape, and forensic experts demand very robust and accurate results. This complex landscape leaded us to tackle the problem considering robust evolutionary algorithms (EAs) [11] to search for the optimal values of the twelve registration transformation parameters. In [5], CMA-ES [12] and different real-coded genetic algorithms [13] were applied, achieving very promising results in some problem instances.

3. SOURCES OF UNCERTAINTY IN SKULL-FACE OVERLAY

The whole CS process is influenced by uncertainty. In particular, SFO is affected by two different sources of uncertainty of different

[1] Notice that, mean square error is not used because of its negative effect when image ranges are normalized in [0, 1].

nature. On the one hand, there is an inherent uncertainty associated with the two different kinds of objects involved in the process, i.e. a skull and a face. On the other hand, there is also uncertainty associated with the 3D-2D overlay process that tries to superimpose a 3D model over a 2D image. Following, we will summarize the main characteristics of both sources and we will review our previous proposal based on the use of fuzzy landmarks to overcome most of the limitations associated with the latter sources of uncertainty.

3.1. Uncertainty inherently associated with the objects under study

We have identified two inherent sources of uncertainty regarding the handled objects (a skull and a face) and their relationship. On the one hand, the *landmark location uncertainty* is related to the extremely difficult task of locating the points in an invariable place, since the definition of any anthropometric landmark is imprecise in its own. Indeed, every forensic anthropologist is prone to locate the landmarks in a slightly different position [14], regardless the means used to represent the involved objects (skull and face), *i.e.* 3D model, 2D photo, video shot, . . .

On the other hand, the *landmark matching uncertainty* refers to the imprecision involved in the matching of two sets of landmarks corresponding to two different objects: a face and a skull. There is a clear partial matching situation. The correspondence between facial and cranial anthropometric landmarks is not always symmetrical and perpendicular, some landmarks are located in a higher position in the alive person face than in the skull, and some others have not got a directly related landmark in the other set [2]. Besides, the facial soft tissue depth varies for each cephalometric landmark and also for every person group (regarding age, race, and sex).

3.2. Uncertainty associated with the 3D skull model-2D face photo overlay process

The uncertainty associated with the 3D skull-2D face overlay is not inherent to the objects themselves but to our approach, where we try to overlay a 3D model and a 2D image. As done in Section 3.1, we can also distinguish between landmark matching and landmark location uncertainty. However, the nature of these two sources of uncertainty is different in the current case.

On the one hand, the landmark location uncertainty refers to the difficulty of locating landmarks with the accuracy required for the automatic overlay of a 3D skull model and a 2D face photo. The ambiguity may arise from reasons like variation in shade distribution depending on light condition during photographing, unsuitable camera focusing, poor image quality, face pose in the photograph, partial or whole landmark occlusion, *etc.*

Forensic experts are prone to only locate those landmarks which can be unquestionably identified in the skull and in the face. Therefore, they are usually only able to locate a reduced set of all the available cephalometric landmarks.

On the other hand, the matching uncertainty refers to the negative influence of a small number of landmarks with an unsuitable spatial distribution in the quality of the SFO results. This effect happens when the landmarks guiding the optimization method are coplanar or near-coplanar.

Due to landmark coplanarity the Equation 1 becomes undetermined (or near-undetermined), *i.e.* there is uncertainty (there is not enough information or it is imprecise) regarding which of the possible solutions is the best. As a consequence, it is not possible to numerically distinguish among the different resulting (after a search process) sets of projection parameters which originate different SFO results. In [15] we experimentally demonstrated the strong negative impact of coplanar landmarks in the quality of the SFO results derived by our automatic procedure. Having a reasonable number of anthropometrical landmarks located in different planes becomes a real need for the good performance of the method.

3.3. Imprecise landmarks: a fuzzy set-based approach

Our approach is based on allowing the forensic anthropologist to perform an imprecise *location of cephalometric landmarks*. By using imprecise landmarks, (s)he can locate the landmark as a region instead of as a crisp point as usual. The size of the region defined by the forensic expert will become a measure of the landmark uncertainty (the broader the region, the higher the uncertainty in the location of that landmark).

Notice that, by marking landmarks in an imprecise way, we manage to solve the problems related to three of the four uncertainty sources analyzed at the same time. First, the inherent uncertainty of the landmark location in the missing person photograph can be properly tackled. In the same way, the forensic experts are able to deal with the location of landmarks whose position they cannot determine accurately due to the photograph conditions with the proper level of confidence (using imprecise regions of different sizes). As a consequence, we will allow them to deal with the extremely difficult task to increase the number of selected landmarks. As explained, those additional landmarks are essential to face the coplanarity problem in the automatic search of the best SFO. Only the landmark matching uncertainty has been left for future works.

The imprecise landmark location approach was implemented through two alternative models of imprecise landmarks: weighted and fuzzy ones. We summarize the fuzzy one since it achieved better skull-face overlay results. For a detailed description of both approaches the interested reader is referred to [7].

The fuzzy landmark approach is based on allowing the forensic experts to locate the cephalometric landmarks using ellipses and on considering fuzzy sets to model the uncertainty related to them. Besides, we have also considered fuzzy distances to model the distance between each pair of craniometric and cephalometric landmarks.

We have defined a fuzzy landmark as a fuzzy convex set of points having a nonempty core and a bounded support. That is, all its α-levels are nonempty bounded and convex sets. In our case,

since we are dealing with 2D photographs with an $x \times y$ resolution, we have defined the fuzzy landmarks as 2D masks represented as a matrix M with $m_x \times m_y$ points (*i.e.*, a discrete fuzzy set of pixels). Each fuzzy landmark will have a different size depending on the imprecision on its localization but at least one pixel (*i.e.* crisp point related to a matrix cell) will have membership with degree one.

These masks are easily built starting from two triangular fuzzy sets $\tilde{V}$ and $\tilde{H}$ modeling the approximate vertical and horizontal position of the ellipse representing the location of the landmark, thus becoming two-dimensional fuzzy sets.

An example of these fuzzy cephalometric landmarks is given in Figure 1, where the corresponding membership values (calculated using the product t-norm) of the pixels of one of those landmarks is depicted on the right.

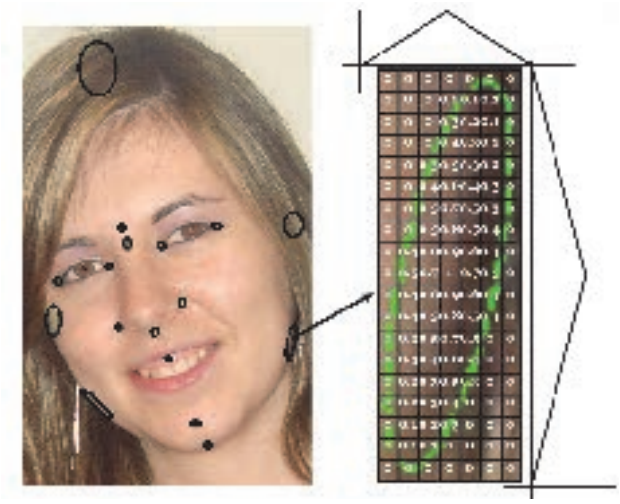

Fig. 1. Example of fuzzy location of cephalometric landmarks (on the left) and representation of an imprecise landmark using fuzzy sets (on the right).

Now we can calculate the distance between a point (which will be the pixel constituting the projection of a 3D craniometric landmark on the 2D face photo) and a fuzzy landmark (the discrete fuzzy set of pixels representing the imprecise position of the cephalometric landmark).

If we denote as $d_i = d(x, \tilde{F}_{\alpha_i})$ the distance from point x to the α-level set $\tilde{F}_{\alpha_i}$ (in this specific case, this is the minimum Euclidean distance from point x to the all the points in α_i), then the distance from the point to the fuzzy landmark $\tilde{F}$, can be expressed by:

$$d * \left(x, \tilde{F}\right) = \frac{\sum_{i=1}^{m} d_i \cdot \alpha_i}{\sum_{i=1}^{m} \alpha_i}$$

Note that the implemented distance between a point and a fuzzy set of points is quite similar to that defined in [16]. In fact, it has been already used in other image processing applications in [17].

Therefore, we modified the original definition of our evolutionary SFO technique's fitness function as follows:

$$fuzzy\ ME = \frac{\sum_{i=1}^{N} d_i * \left(f\left(cl^i\right), \tilde{F}^i\right)}{N} \qquad (3)$$

where N is the number of considered landmarks; cli corresponds to every 3D craniometric landmark; f is the function which defines the geometric 3D-2D transformation; $f(cl^i)$ represents the position of the transformed skull 3D landmark cli in the projection plane, that is to say, a crisp point; $\tilde{F}^i$ represents the fuzzy set of points of each 2D cephalometric landmark; and, finally, $d*(f(C_i), \tilde{F}^i)$ is the distance between a point and a fuzzy set of points.

4. A COOPERATIVE COEVOLUTIONARY ALGORITHM TACKLING THE LANDMARK LOCATION UNCERTAINTY IN CRANIOFACIAL SUPERIMPOSITION

EAs have been applied to many types of problem domains, such as parameter optimization and machine learning. A very natural, and increasingly popular extension when problems domains are potentially complex, or when it is difficult or impossible to assess an objective fitness measure for the problem, is the class of so-called coevolutionary algorithms (CEAs) [8]. In such algorithms, fitness itself becomes a measurement of interacting individuals. This ostensibly allows the potential for evolving greater complexity by allowing pieces of a problem to evolve in tandem, as well as the potential for evolving solutions to problems in which such a subjective fitness may, in fact, be necessary (*i.e.*, game playing strategies). Hence, a coevolutionary algorithm is an EA (or collection of EAs) in which the fitness of an individual depends on the relationship between that individual and other individuals [18].

Depending on the nature of the interactions among individuals we can distinguish between competitive and cooperative CEAs. In the former, each specie competes with the rest. In the latter, named cooperative coevolutionary algorithms (CCEAs) [19], all the species collaborate to build a solution for the problem. The originally-stated aim of CCEAs was to attack the problem of evolving complicated objects by explicitly breaking them into parts, evolving the parts separately, and then assembling the parts into a working whole.

This is the goal of the current proposal in which two different but complementary problems arise. On the one hand, we want to know the best set of transformation parameters resulting in the best possible SFO. On the other hand, SFO quality is measured based on the distances among two set of landmarks, where the location of the cephalometric one is uncertain. We only know that they are located somewhere inside a region delimited by the forensic expert (imprecise landmark). Hence, we can try to find the exact locations of the cephalometric landmarks in that region. However, the only way to determine them is by looking for the best SFO, assuming that the most precise location of the landmarks implies the chance

to achieve the most precise SFO. That is to say, we need to look, at the same time, for the best set of transformation parameters and for the most precise cephalometric landmarks locations.

To do that, we have implemented a CCEA where two populations optimize the set of transformation parameters and the location of the cephalometric landmark, respectively. For the former population we consider a coding scheme representing the twelve registration transformation parameters in a vector of real numbers while for the latter we consider a variable-length integer-valued chromosome, whose size corresponds with the number of pair of landmarks used. Both populations need to collaborate/interact to construct a solution for the main problem, that is to achieve the best possible SFO.

The question of how a practitioner determines collaborators or competitors may be among the most important design decisions for the successful application of CEAs [20]. The most obvious (and computationally expensive) method to evaluate an individual in a coevolutionary setting is for an individual to interact with all possible collaborators or competitors. In the case of binary interactions, this is sometimes called complete pairwise interaction. An alternative extreme is for an individual to be involved in only a single interaction. Such a choice leaves open the obvious question of how to pick the collaborator or competitor. Of course, between these two extremes there is a whole host of possibilities that involve some subset of interactions. Again, collaborators/competitors for such interactions may be chosen in a variety of ways from uniformly random, to fitness biased methods. There are mainly three attributes of this choice, suggesting a wide range of possible strategies. They are briefly described below:

- Interaction sample size: the number of collaborators/competitors from each population to use for a given fitness evaluation.
- Interaction selective bias: the degree of bias of choosing a collaborator/ competitor. For example, an individual could be selected either randomly or based on the fitness value.
- Interaction credit assignment: the method of credit assignment of a single fitness value from multiple interaction-driven objective function results. The main examples here are the minimum, the maximum and the mean of all the fitness values.

In our implementation of the CCEA we tested many different options for these three parameters. As interaction selective bias we use both the best individuals and random ones. The minimum, the maximum and the mean were tested as credit assignment mechanisms.

The transformation parameters population uses SBX crossover [5] while the landmark locations population uses multi-point crossover. Random mutation is used in both cases, constraining the possible values for the landmark location to all the pixels inside the region corresponding to the imprecise landmark the forensic expert located in the image.

In the following section we show the set of parameters that results in the best SFO results.

5. EXPERIMENTS

Our experimental study will involve six different SFO problem instances corresponding to three real-world cases previously addressed by the staff of the Physical Anthropology lab at the University of Granada (Spain) in collaboration with the Spanish scientific police.

All those identification cases were positively solved following a computer-supported but manual approach for SFO. We will consider the available 2D photographs of the missing people and their respective 3D skull models acquired at the lab by using its Konica-Minolta 3D © Lasserscanner VI-910.

The experiments developed in this section are devoted to study the performance of the coevolutionary-based approach to model the imprecise location of cephalometric landmarks within our SFO method in comparison with the previous fuzzy set-based proposal. With this aim, we first show the parameter setting considered. Then, we introduce each of the six selected real-world SFO problems to be tackled together with the obtained results and their analysis.

5.1. Experimental design

We used CMA-ES as the evolutionary algorithm for the case of fuzzy set-based approach [7] guided by the corresponding objective function (Equation 3) and we considered the following set of parameters:

initial θ (mutation distribution variance)	= 0.1
λ (population size, offspring number)	= 100
μ (number of parents/points for recombination)	= 15

The rest of the parameters are the default ones, reported in [12].

For the case of the coevolutionary approach, we performed many different combinations of parameters[2] under the restriction of 560,000 evaluations of the fitness function (according to the CMA-ES conditions). The set of parameters considered are the following:

# generations	= 600
T size	= 450
L size	= 25
T and L crossover probability	= 0.9
T and L mutation probability	= 0.2
T and L tournament size (for RCGA)	= 2
SBX η parameter (for population T)	= 0.1
Interaction sample size and selective bias:	
# best selected individuals in T	= 1
# random selected individuals in T	= 1
# best selected individuals in L	= 2

[2] These preliminary experiments are not included because of a lack of space

# random selected individuals in L	= 2
Interaction credit assignment	= m

where T is the population of the transformation parameters, L is the population of landmark locations and *m* corresponds to the minimum value from the multiple interaction-driven objective function results.

Thirty independent runs were performed for each case in order to avoid bias in the results and to compare the robustness of both proposals.

We would like to have a quantitative measure allowing us to benchmark the achieved outcomes. Unfortunately, the ME values obtained by each approach are not fully significant to perform a comparison because of the different objective functions to be minimized. In addition, there is not a direct correspondence between ME values and the visual representations as it was pointed out by the experts in [7].

Due to the latter reasons, we adopted an alternative, specifically designed image processing scheme to evaluate the performance of every SFO approach called “area deviation error” (ADE) [7, 15]. In ADE the percentage of the head boundary that is not covered by the area of the projected skull is computed as a measure of the quality of the overlay. Figure 2 shows an example of the application of this evaluation procedure.

Fig. 2. Example of area deviation error procedure.

From left to right, original photographs (top) and projected skull (bottom), intermediate images with the head boundary (top) and binary skull (bottom), and final XOR image (right most) with the corresponding ADE value below the image.

5.2. Case studies

As said, all the SFO instances tackled in this work are real-world cases previously addressed by the Physical Anthropology lab at the University of Granada (Spain). We briefly introduce them as follows.

The first case study happened in Málaga, Spain. The facial photograph of this missing lady was provided by the family and the final identification done by CS has been confirmed. The forensic experts manually selected a set of fifteen 2D cephalometric landmarks on the face present in the photo, following an imprecise approach (first photograph of Figure 3).

Fig. 3. Case studies: photograph of the missing person with the corresponding set of imprecise landmarks.

First row, first image corresponds to case study 1. First row, second image corresponds to case study 2. The other four images (last image of first row and the three images in the second row) belong to case study 3, poses 1, 2, 3 and 4, respectively.

The second real-world case considered corresponds to a Moroccan woman whose corpse was found in the South of Spain. There is a single available photograph corresponding to that one in the alleged passport. In this case of study, the forensic experts identified 16 cephalometric landmarks following an imprecise approach (second photograph of Figure 3).

Finally, The third case study happened in Cádiz, Spain. The four different photographs were provided by the relatives, which acquired them at different moments and in different poses and conditions. Hence, this case study consists of four distinct SFO problem instances. The forensic experts were able to locate 14, 16, 15 and 8 landmarks following an imprecise approach for poses 1, 2, 3 and 4, respectively (third to sixth photograph of Figure 3).

5.3. Coevolution vs fuzzy landmarks

Table 1 shows the run time of both approaches in every SFO instance. Our coevolutionary proposal is, between, ten and thirty times faster than the fuzzy-evolutionary method. As said, these big differences arise mainly because of the high computational effort needed to calculate the fuzzy distance between each pair of crisp-fuzzy landmarks in every fitness evaluation.

Table 2 presents the ADE values for the obtained SFOs in the previous six cases, distinguishing between fuzzy-evolutionary and coevolutionary approaches. The minimum (m), maximum (M), mean (ϖ), and standard deviation (σ) values of the thirty runs performed are shown for each case.

Mean and standard deviation ADE values show a better performance of the fuzzy-evolutionary approach. However,

according to the minimum ADE results, the coevolutionary approach outperforms in four of the six cases. The corresponding SFO representation are depicted in Figure 4. As ADE values confirm, there are not big visual differences among the best SFO obtained following both approaches. In fact, visual differences can be mainly distinguished for those cases with bigger ADE differences, that is, cases 1 and 3 poses 3 and 4.

Fig. 4. Best superimposition obtained following a fuzzy-evolutionary (first row) and a coevolutionary (second row) approaches.

From left to right, case studies 1, 2, 3 (poses 1 to 4).

Table 1 Mean run time needed to execute the fuzzy-evolutionary and the coevolutionary approaches over each of the SFO instances.

Approach	Run time					
	Case 1	**Case 2**	**Case 3, 1**	**Case 3, 2**	**Case 3, 3**	**Case 3, 4**
Fuzzy	55’	190’	63’	82’	97’	210’
Coevolution	1.8’	4.8’	3.9’	2.7’	3.2’	4.6’

Table 2 Mean run time needed to execute the fuzzy-evolutionary and the coevolutionary approaches over each of the SFO instances.

Case	Approach	ADE			
		m	M	ϖ	σ
1	Fuzzy	15.20	45.98	21.56	10.60
	Coevolution	**12.20**	**22.16**	**17.44**	**2.74**
2	Fuzzy	14.16	**15.98**	**14.97**	**0.43**
	Coevolution	**13.04**	25.23	17.23	3.37
3, 1	Fuzzy	**14.54**	**20.65**	**16.50**	**1.14**
	Coevolution	15.42	41.92	30.19	7.11
3, 2	Fuzzy	23.67	**26.07**	**24.78**	**0.57**
	Coevolution	**23.59**	37.71	31.24	3.84
3, 3	Fuzzy	17.32	**20.62**	**18.97**	**0.88**
	Coevolution	**14.22**	38.55	26.57	6.58
3, 4	Fuzzy	**16.70**	**18.14**	**17.38**	**0.36**
	Coevolution	19.14	34.36	28.22	3.37

6. CONCLUDING REMARKS AND FUTURE WORKS

In this paper we have proposed a coevolutionary approach to deal with imprecise cephalometric landmarks in the SFO process. By using a CCEA we are able to look for both the best transformation parameters and the best landmark locations at the same time.

Our proposal has been tested on six complex real-world identification cases and it has been compared with our previous fuzzy-evolutionary method. CCEA is a promising approach for SFO since it achieves outstanding results in very short time (between ten and thirty times faster than our previous method). Furthermore, the best coevolutionary results are better than the fuzzy-evolutionary ones in four of the six problem instances.

However, the robustness of the method should be increased. With that aim, we are studying new ways of interaction between the two populations.

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Deceleration Impact Experiments and Deceleration Injury Mechanism Analysis on the Thoracic and Abdominal Organs

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ABSTRACT *Objective* It takes animal organs as models to study the process and mechanisms of thoracic and abdominal organs deceleration injury to establish a more reasonable basis for the injury assessment. *Methods* New Zealand rabbits were dissected along the cross-section of the chest near the diaphragm as animal models. The chest and organs were exposure. The supine (Group A) and the prone (Group B) positions were designed to be fixed in the crash test platform. The movable platform free fell from fixed height and hit the fixed platform. The high-speed camera was used to record the whole deceleration impact process. After completion of the experiment, the image sequence analysis software was used to analyze the collision process. *Results* The injured areas were all at the impact side. The high-speed camera showed that before ribs squeezing the lung at the hedge side, organs had hit the chest wall at the impact side then compressed. When ribs deformed at the hedge side, they did not compress organs immediately but with a time interval before contact and compression. The deformation of Group A was significantly higher than Group B, but there were no significant differences for the severity of organ damages. *Conclusions* In deceleration injury, the thoracic and abdominal organ damage is mainly due to the inertia impact between organs and the chest wall, while it is of no direct correlation with the compressional deformation. Thus, the AIS injury assessment criteria have serious problems, and it needs to find a new scientific assessment method.

KEY WORDS Injury, Impact, Liver, Deceleration impact, Animal experiment, High speed camera, Forensic science

1. INTRODUCTION

When the vehicle encountered obstacles in the process of moving, it could be involved in a sharp slowdown with large probability. For the fighter, it also needs a sharp slowdown process in the moment of landing for various venues. In these deceleration situations, abdomens of occupants inside the aircraft / vehicle may have a powerful contact collision with the machine parts causing organ damage. Therefore, it is necessary to study the biomechanics mechanism of organ injury generated by the deceleration impact.

As a reflection of existing research results in this field, the Injury Severity Score (ISS) is an established medical score to assess trauma severity, and the current damage assessment is using the AIS standard related to ISS [1, 2]. It correlates with mortality, morbidity and hospitalization time after trauma. It is used to define the term major trauma. And the Abbreviated Injury Scale (AIS) is an anatomically based consensus-derived global severity scoring system that classified each injury in every body region according to its relative severity on a six-point ordinal scale: 1 Minor, 2 Moderate, 3 Serious, 4 Severe, 5 Critical, 6 Maximal (currently untreatable).

Early studies have discovered that organs in the chest and

abdomen are so fragile and of little elasticity that they are very easily to be injured during the impact [3]. And there have been several preliminary conclusions [4] for these organs injury mechanism: 1) During the deceleration impact, organs encounter more substantial squeeze between the anterior abdominal wall and the spine; 2) Viscous injury: due to over-stretch effects and shear effects caused by the increased fluid pressure in the liver on high load; 3) In sudden deceleration, the liver does the inertia movement that stretch lacerations occurr at the site of attachment of blood vessels and ligaments; 4) Ribs occur stabbed at the end of the fracture.

For organs in case of sudden deceleration, their own injury, which is having nothing to do with the external connection but caused by inertial characteristics, is rarely reported in the previous literature. This paper will preliminary study the mechanical effect caused by its inertia characteristics in organs reducer impact process.

Relations among the AIS, the rib fracture and the chest compression:

$$\text{Chest Compression} \rightarrow \text{Rib Fracture} \rightarrow \text{AIS}$$

$$\text{AIS} = -3.78 + 0.1956 * \text{Chest Compression (\%)}$$

Since it is through the classification assessment to determine the injury level, AIS is mainly based on and developed through the dummy experiments

But the dummy is a frame structure. It is a cavity and supported by a bone structure with no soft issues such as organs inside. So, for this method, it can only assess the inner organ damages by the compression degrees of the thoracic and abdominal wall.

For human body, in traffic accidents, each part is moving at the same speed. But when the vehicle stopped, the body in the vehicle is still moving forward due to the inertia. So different parts of the body have different speeds. When the chest hits the vehicle, organs are still moving forward and then impact with the chest wall. Because of the resistance from the rib profile, the extrusion slows done. Thus, the organ impact with the back should be later than with the chest wall.

For AIS, it does not consider the injury differences between deceleration and acceleration. So, it needs to do experiments to study the real mechanism. It should make clear whether the organ deceleration injury is caused from the chest wall impact by the inertia force or from the back compression by the deformation.

In this research, rabbits are taken as the animal model for observing the injury process. The organ impact properties have also been detected to establish a basis for more reasonable assessment on organ injury.

2. MATERIALS & METHODS

Materials：Two groups of New Zealand white rabbits with 9 per group and each weight 2.5 0.1kg (Animal Centre of Daping Hospital); a high-speed camera（PHANTOM V4.3, USA）; and the Biological Impact Device with Free-fall Deceleration Impact Rail [5].

New Zealand white rabbits were anesthetized and then fixed in the experimental platform. After causing them the suffocation death, their abdominal cavities were opened. From the 9th spine, the thoracic cage was cut off and the head was cut. The diaphragm was removed and the lungs were exposed. Placed the chest and organs on the platform of the deceleration device and fix it. Group A: chest plate, back up (Figure 1). Group B: Back plate with chest facing up (Figure 2).

Fig. 1. Group A: Thoracic cross section (before impact)

Fig. 2. Group B: Thoracic cross section (before impact)

Took out the lungs and heart, took pictures, and observed.

Finally, the image sequence analysis software was used to analyze the injury condition.

3. RESULTS

Both groups of lungs collapsed, but no significant changes were seen in the kidneys.

There was bleeding damage on the back panel of Group A (Figure 3). There was bleeding damage on the chest plate of Group B (Figure 4). Both groups were contact injured.

For Group A, as shown in Figure 5, the frames under high-speed camera displayed that, during the deceleration process (the red line on Figure 5), due to the inertia of the organ, it will first collide with the spine, and then it will impact gradually (the point a on Figure 5) with the impact side of the rib wall (the yellow line on Figure 5), and a series of blocked compression motions began. At this time,

the front part of the chest (the blue line on Figure 5) was deformed without constricting the organs. Until the deformation speed of the anterior chest synchronously exceeds the obstructed compression velocity of the organ, the organ is subjected to the deformation force of the chest cavity (the point b on Figure 5). The organ was affected by the inertial force (the point a on Figure 5) before the rib compression force (the point b on Figure 5).

For Group B, as shown in Figure 6, the frames under high-speed camera displayed that, during the deceleration process (the red line on Figure 6), due to the inertia of the organ, it will first collide with the front part of the chest, and then it will also impact gradually (the point a on Figure 6) with the impact side of the rib wall (the yellow line on Figure 6), and a series of blocked compression motions began.

Fig. 3. Group A: After impact

Fig. 4. Group B: After impact

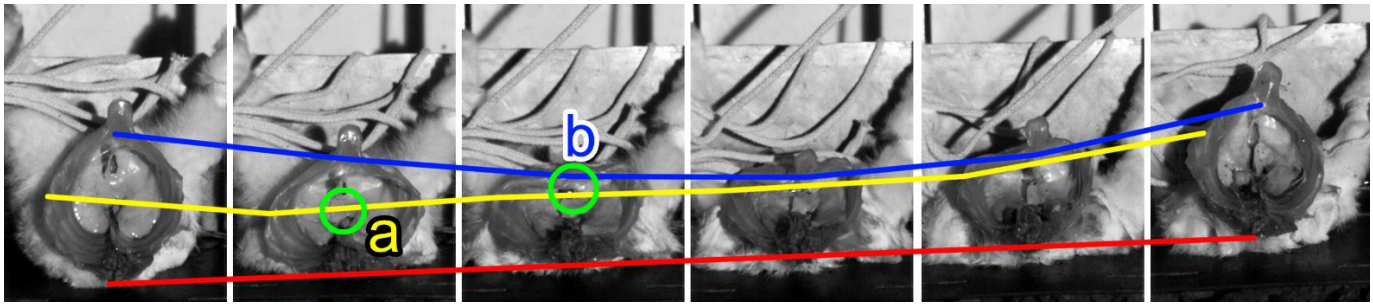

Fig. 5. Group A: High-speed camera shots during the crash

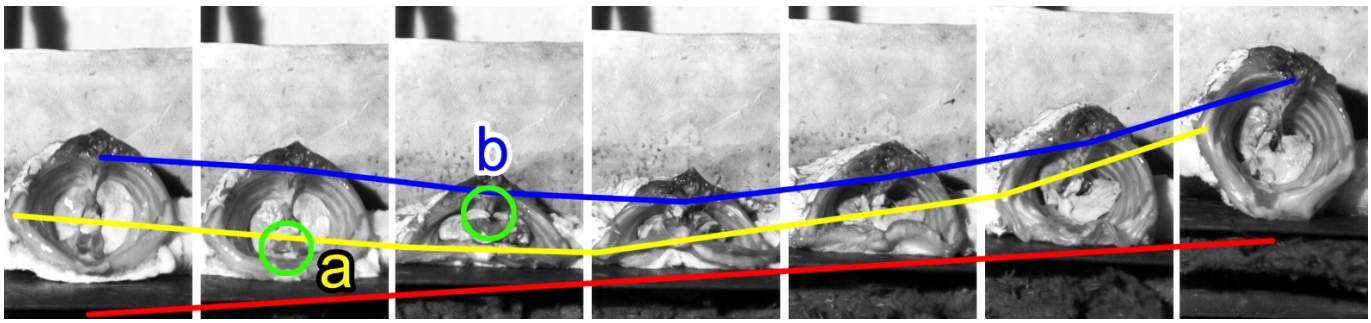

Fig. 6. Group B: High-speed camera shots during the crash

At this time, the back of the chest (the blue line on Figure 6) was deformed without constricting the organs. Until the deformation speed of the anterior chest synchronously exceeds the obstructed compression velocity of the organ, the organ is subjected to the deformation force of the back (the point b on Figure 6). The organ was affected by the inertial force (the point a on Figure 5) before the rib compression force (the point b on Figure 6).

According to the high-speed video time series frame diagram, the deformation in Group A was significantly higher than that in Group B, but there was no significant difference in the severity.

4. DISCUSSION

The experimental results show that: During the deceleration and impact of the liver, a significant laceration occurred on the opposite side of the impact, and no obvious tearing injury was found on the impact side. Although the severity of the injuries was different due to the individual differences in animal tissues, the results still suggest that the opposite side was subjected to a pronounced tensile stress; and the impact stress on the impact side was relatively weak.

The results of studies on the mechanism of hepatic impact injury have been summarized in the past as crush injury, stretch injury and shear injury caused by increased intrahepatic fluid pressure, traction tears of peripheral blood vessels and ligaments, and stab wounds. [4] The mechanism of stretch injury caused by increased intrahepatic fluid pressure is different from that of this experiment. The former is mainly due to the explosive stretch injury caused by a sudden increase in the pressure of the intrahepatic fluid caused by the impact of the liver in vivo in the presence of liquid filling. In this experiment, the liver was obtained after the animals were sacrificed. There is no liquid filling condition in the liver. Therefore, the tear damage generated in the experiment should not be due to a sudden increase in intrahepatic fluid pressure. In this experiment, the injury mechanism of the liver should be that during the impact, the liver is in the force field due to its own inertia and impact reaction force, and there is only a constraint between the tissue and the tissue in the heel-side tissue, so the opposite side is stretched. Stress can easily cause lacerations. The impact side did not see a significant laceration during the impact. This is due to the fact that the impact-side tissue is not only bound by tissue-tissue constraints, but also because the impact-side tissue is in close contact with the impact contact surface, and the interface between different media can produce a certain amount of friction thus hinders mutual displacement between different media. This boundary condition considerably weakens the stretch effect on the impact side of the liver, so that the tear damage due to stretching can be reduced to a corresponding extent.

In actual traffic accidents, there are two mechanical mechanisms for the tearing of the human liver: The first is due to the sudden increase in intrahepatic fluid pressure during the impact of the impact of the liver bursting tear injury occurs, and its mechanical action is from the inside out; the second is the impact of the heel side of the liver stretched the role of stress caused by its tear damage, and its mechanical action is from outside to inside.

For the dose-effect relationship between impact energy and injury level in liver impact injury, relevant literature [6] has been reported in detail. This experiment focuses on the study of the mechanism of injury in the process of hepatic impact injury. It is expected to help to clarify the mechanical mechanism of liver injury that is common in traffic accident injuries to a certain extent, and to provide some new experimental methods and certain Experimental basis.

The biomechanical mechanism of liver injury is a very broad and complex research direction. The results of the current study are mixed with far-off non-serialized and standardized data such as the impact experiment of human fresh entities, and the injury experiment of anesthetized animals caused by seat belts. The shape, area, impact velocity, and impact mode of the impactor can undergo complex changes, leaving many gaps to be explored. [4] Due to ethical constraints, the liver impact injury experiment cannot obtain sufficient data from human morbidity experiments. Therefore, it is necessary to carry out extensive research on new experimental methods, experimental models, and alternatives.

With the appearance of new experimental instruments and test methods, including the multi-functional small biological impact machine developed by *Prof.* Zhiyong Yin and others [7], as well as the emergence of various biological substitutes or simulants, it provides good conditions for biomechanical research. Biological substitutes have similar organizational structure and mechanical properties to human organs, and also have the ability to reflect different degrees of damage. They can be used under different impact conditions (impact direction, form, impact velocity, loading mode, and some living organisms cannot be achieved. (Conditional) biomechanical studies. These biological substitutes or mimics can provide meaningful suggestions for studying the protective principles of liver injury.

The thoracic frame formed by the ribs and spine is anteriorly soft and hard. Their compression is not the same. If it is squeezed, the injury before and after it should be different. However, the experimental results show that under the opposite placement mode, the deceleration impact of the visceral organs corresponding to the spine parts is the same (all with the same degree of injury on the impact surface). This shows that organ injury is not thoracic compression, but mainly inertial collisions.

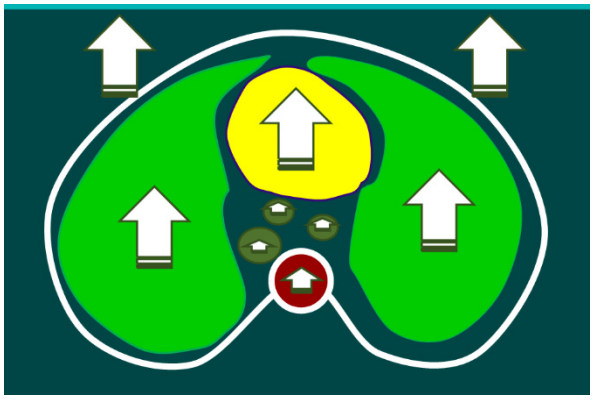

Fig. 7. Effect of deceleration process on organs (viscera)

In the case of squeezing deformation, there should be traces of damage on both the upper and lower organs, but in the experiment, there were only traces and no traces. Accelerated injuries are caused by squeezing, such as damage caused by a blow, but the

reverse is the opposite (Figure 7), such as damage caused by a car accident. Due to the difference in force of the type of impact, the shape of these two types of injuries is very different.

Inertial injury is only damage to the contact surface. The crush injury is symmetrical, and it should be that both the contact surface and the corresponding surface are damaged.

In previous studies on road traffic injuries, many researchers believed that occupant injury to the thoracic and abdominal organs was caused by external forces acting on the ribs, which in turn caused internal organs to squash and cause injuries. The indicators including chest and abdomen in the assessment of existing vehicle safety performance are still based on the amount of chest compression. The results of this experiment show that the damage to the thoracic organs during deceleration injury is mainly caused by the damage of the organs against the chest wall. Therefore, there are serious problems in the AIS damage assessment criteria and new scientific evaluation methods need to be found.

6. CONCLUSIONS

Due to the development of computer technology and the rise of the artificial intelligence wave, some research teams in the academic community are currently working on relevant research through computer modeling, virtual simulation, and intelligent analysis. However, the premise of all virtual technologies is still inseparable from the verification of real data. This experiment has shown that, in the deceleration injury, the thoracic and abdominal organ damage is mainly caused by impact due to the organ inertia, and it is of no direct correlation with the compressional deformation. The conclusion is of great significance for the establishment of a more rational method of chest and abdomen organ damage assessment of injury mechanisms.

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Effects of Heat Exposure Duration on Saliva Traces on Cigarette butts as Forensic Identification Tools

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ABSTRACT Identification processes are not only conducted on the dead bodies of criminal victims, but also on the evidence found at the location. The length of time between the crimes happening and the investigation of the evidence is a problem in relation to the blood group identification process through saliva traces on cigarette butts. Wet saliva usually becomes trace in an hour and 40 minutes at room temperature, and up to less than 3 hours if there any influencing factors. The purpose of this research is to analyze the effects of heat exposure duration on the protein content of the saliva traces on cigarette butts in order to help the forensic blood group identification process. A time series design was used in this research in which 18 cigarette butts were collected from 6 individuals of blood groups A, B, and AB. The samples were then incubated for 1.3 and 6 hours respectively. The protein content was determined using a Trizol reagent and Spectrophotometer UV. Statistical analysis using a T-test was conducted to analyze the results. There was a decrease in the protein content of the saliva trace samples at the time points of 1, 3 and 6 hours. The protein content of the saliva could still be detected at the time points of 1, 3 and 6 hours. These findings suggest that the protein analysis of saliva trace samples on cigarette butts can be used in the forensic blood group identification process.

KEY WORDS Cigarette butts, Saliva traces, Protein, Forensic identification, Forensic science

1. INTRODUCTION

Forensic identification is the methods undertaken by investigators to investigate the identity of the victims and culprits. The identification processes are not only conducted on the dead body of criminal victims, but also on the evidence found at the location (Gani, 2002). In the murder case that happened on 14th May 2013 in Bangkingan Madura, East Java, several items of information like the smoking habits, brand, lip print, finger print and even saliva traces can be detected on the cigarette butt as evidence found (Hardjanto Pudji, 2015). The saliva traces can be used as a specimen in blood group identification which is a secondary identification component (Rogers et al, 2005). The glicoprotein content in saliva is a component used to determine blood group in the ABO and Lewis system in individuals who have a secretor blood group (Albertolle *et al*., 2017). A research study conducted at a State Police Laboratory in Jakarta found that 75% of police officers have a secretor blood group. On the other hand, 85% of the world's population have a non- secretor blood group.

The length of time between crimes happening and the investigation of the evidence is a problem in the blood group identification process through the saliva traces on cigarette butts. Wet saliva usually become trace in an hour and 40 minutes at room temperature, and up to less than 3 hours if there any influencing factors (Jellinghaus *et al*., 2015). Early blood group identification through saliva samples on cigarette butt evidence needs to be conducted in order to help investigate the identity of the victims and culprits. The aim of this study is to determine the time span for blood group analysis through saliva trace samples down to the remaining protein levels.

2. METHOD

This study was a laboratory experiment using a time series design which used 1, 3 and 6 hours at room temperature as the respective intervals. The samples used in this study consisted of 18 cigarette butts. In this study, the saliva on the cigarette butts was set up as the independent variable, while the dependent variable was the identification of the forensic blood type. The control variable in this study was the time duration used by the researchers that ranged between 1 hour, 3 hours and 6 hours to determine the decreasing protein count in saliva. The confounding variable was the temperature because it can lead to the saliva drying on the cigarette

butts. This study was conducted in the TDC (Tropical Disease Centre) Laboratory at the Tropical Disease Centre Institute of Airlangga University, Surabaya and the forensic laboratory of Saiful Anwar Public Hospital, in Malang. A non-parametric statistic test (normality test, homogeneity, t test) with linear regression analysis was used to determine the influence of the exposure time to the temperature with the amount of the protein level in the saliva on the cigarette butt.

3. RESULTS AND DISCUSSION

The samples were obtained from six cigarette butts smoked by six individual research subjects who know their blood type. The cigarette butt with sample number 1 (A1 - F1) was swabbed one hour after being smoked; the cigarette butt with sample number 2 (A2 - F2) was swabbed three hours after being smoked; the cigarette butt with sample number 3 (A3 - F3) was swabbed six hours after being smoked. The estimation of the protein level in saliva was done using a Spectrophotometer using a 280 nm wavelength, which used an absorbance ratio of 280/260 to determine the correction factor that exists in the table. The protein level is determined by the following formula: protein level (mg / ml) = A280 x correction factor x dilution.

Table 1 Average protein level.

No.	Exposure duration at room temperature (hours)	Mean protein content (mg/ml)
1	1	1,43
2	3	1,49
3	6	1,86

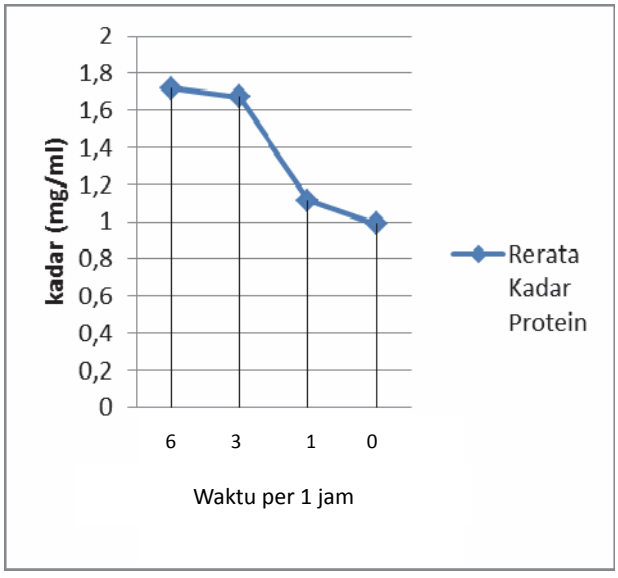

Fig. 1. Curve of Average Protein Level - Exposure Duration at Room Temperature

The protein level of the cigarette butts in Table 6 shows that after one hour post-smoke, the swab ranged from 0.686 mg/ml to 2,958 mg/ml, after 3 hours post-smoke the swab ranged from 1.355 mg/ml to 1.818 mg/ml, and after 1 hour post- smoke the swab ranged from 0.564 mg/ml to 1.839 mg/ml. This was influenced by the saliva spotted surface area of the subjects on the cigarette butts and the salivary degree due to hydration. The greater surface area of the salivary spots and its corresponding hydration level, the greater the salivary protein that is obtained. Table 1 shows the average protein level at each swab time interval on the cigarette butt. The data shows a decreasing protein level over the exposure duration at room temperature. Figure 1 shows the decreasing curve of the protein level. There was a significant decrease in the protein level of the 3rd swab compared to the 6th swab.

The protein level data of each exposure time group had a normal distribution with a significance value of >0.05. In the homogeneity test using a T test, the significance value was 0.086 (>0.05), which means that there were at least two groups where there was no significant difference in the protein level. In the Post Hoc test, the homogeneity test was performed between the groups of exposure time; a significant difference was found between the group with 1 hour of exposure time and the 6-hour group with a significance value of 0,038 (<0,05). The other tests do not show a significant difference with a significance value of > 0.05. The correlation test between exposure time at room temperature and the protein levels using a Pearson correlation test, shows a significance value of 0.013 (<0.05). This means that there is significant correlation between exposure time at room temperature and salivary protein levels. The correlation value is -0.499, indicating that the longer the exposure time, the smaller the level of salivary protein. The correlation strength is moderate.

4. CONCLUSION

The exposure time at room temperature has been shown to influence the levels of protein in the saliva on cigarette butts. There is a decreasing level of protein in the salivary swab at 1 hour, 3 hours and 6 hours after being smoked with an average level 1.717969 mg/ml, 1.673408 mg/ml, 1.113023 mg/ml, and 0.988335 mg/ml respectively. Statistically, there is a significant correlation between the duration of the exposure time at room temperature with salivary protein level. Moreover, the correlation value shows that the longer the exposure time, the smaller the level of salivary protein, the correlation strength is moderate. The mean value of the protein content of the salivary swab 1 hour after bite with the salivary swab 6 hours after bite was also obtained.

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ERRATA: CORRIGENDUM & APOLOGY

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There once had been a mistake in the publication of a wrong document, which has been corrected.

Because of some mistakes in publishing, the most content of Professor James Byrne's paper (Ref.4.) had been wrongly typesetting and published online at Forensic Sci Sem, Vol. 7 No. 2., while the original correct article failed to be published in time. Since Professor James Byrne's paper (Ref.4.) is the only English reference for that article. It had been wrongly typed as the text and had not gotten valid proofreading. The wrong published document has been revoked and it has already published the correct manuscript online.

About this mistake, we have already replied to the Taylor press.

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We apologize to Professor James Byrnethe again.

Ref.4.

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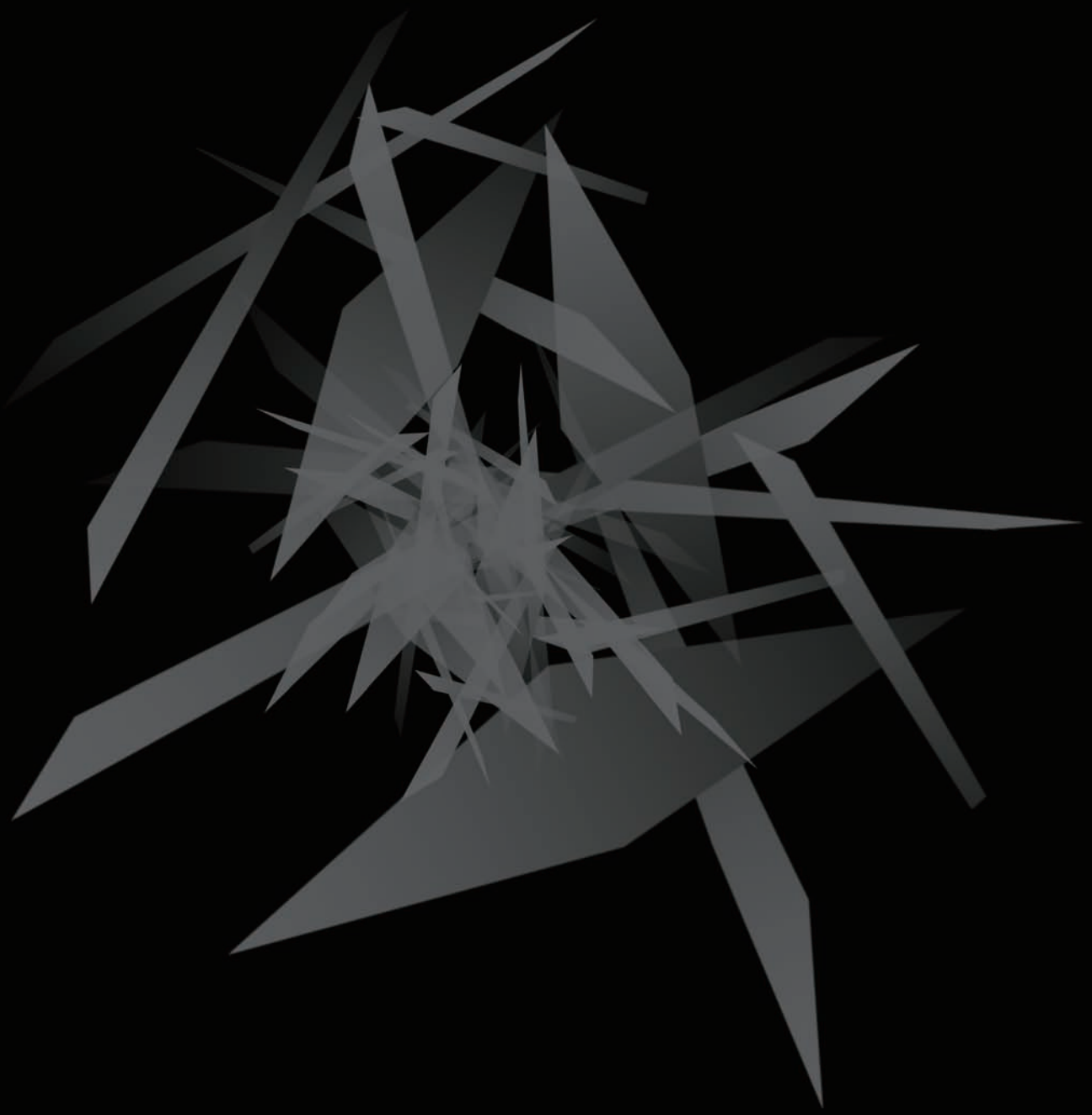

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