Evaluation and Analysis of a Software Prototype for Guidance and Implementation of a Standardized Digital Forensic Investigation Process

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Abstract—**Performing a digital forensic investigation requires a standardized and formalized process to be followed. The authors have contributed to the creation of an international standard on digital forensic investigation process, namely ISO/IEC 27043:2015, which was published in 2015. However, currently, there exists no application that would guide a digital forensic investigator to implement such a standardized process. The prototype of such an application has been developed by the authors and presented in their previous work. The prototype is in the form of a software application which has two main functionalities. The first functionality is to act as an expert system that can be used for guidance and training of novice investigators. The second functionality is to enable reliable logging of all actions taken within the investigation processes, enabling the validation of use of a correct process. The benefits of such a prototype include possible improvement in efficiency and effectiveness of an investigation and easier training of novice investigators. The last, and possibly most important benefit, includes that higher admissibility of digital evidence will be possible due to the fact that it will be easier to show that the standardized process was followed. This paper presents an evaluation of the prototype. Evaluation was performed in order to measure the usability and the quality of the prototype software, as well as the effectiveness of the prototype. The evaluation of the prototype consisted of two main parts. The first part was a software usability evaluation, which was performed using the Software Usability Measurement Inventory (SUMI), a reliable method of measuring software usability and quality. The second part of evaluation was in a form of a questionnaire set up by the authors, with the aim to evaluate whether the prototype meets its goals. The results indicated that the prototype reaches most of its goals, that it does have intended functionalities and that it is realatively easy to learn and use. Areas of improvement and future work were also identified in this work.**

Keywords- software evaluation, implementation prototype, digital forensics, digital forensic investigation process model, standardization, ISO/IEC 27043

I. INTRODUCTION

Dealing with digital evidence requires a standardized and formalized process in order for digital evidence to be accepted in a court of law [1].

An international standard on digital forensic investigation process, named "ISO/IEC 27043:2015 information technology- security techniques - incident investigation principles and processes", was published in March 2015 by the International Standardization Organization (ISO) [2]. The authors have contributed significantly to the development of the standard through their research outputs.

The problem which this paper is addressing is that there is no appropriate software application that would guide one through the implementation of a standardized and harmonized digital forensic investigation process. In their previous work, the authors proposed a comprehensive and harmonized digital forensic investigation process model [3] and an implementation prototype in the form of software application [4]. This paper specifically concentrates on evaluation of the proposed prototype and identifying its potential benefits and flaws.

The remainder of the paper is structured as follows: Section 2 provides background on digital forensics, past work on the digital forensic investigation process and the comprehensive and harmonized digital forensic investigation process model proposed by the authors in their previous work [3]. Following that, Section 3 gives an overview of the prototype. Section 4 presents results from the evaluation of the prototype. Section 5 concentrates on discussing and critically evaluating the prototype and its potential use and benefits. Section 6 concludes this paper and gives indications of future work.

The following section provides a brief background to our paper.

II. BACKGROUND

The subsections which follow provide background on the following topics: First, background on digital forensics investigation readiness is provided in order to introduce the reader to the basics of the subject. After that, we provide a short discussion on past work on the digital forensic investigation process. Last, but not least, we provide an overview of the comprehensive and harmonized digital forensic investigation process model proposed by the authors in their previous work [3], which ultimately served for standardization of the field [2]. This process model represents the basis of the prototype evaluated in this paper and is, therefore, explained here, although at a high level only due to space constraints.

The following section gives an overview of Digital Forensics.

A. Digital Forensics

In this section the authors provide a definition of digital forensics as assembled from various sources within previous research by the authors. The digital forensic investigation process is defined as the use of scientifically-derived and

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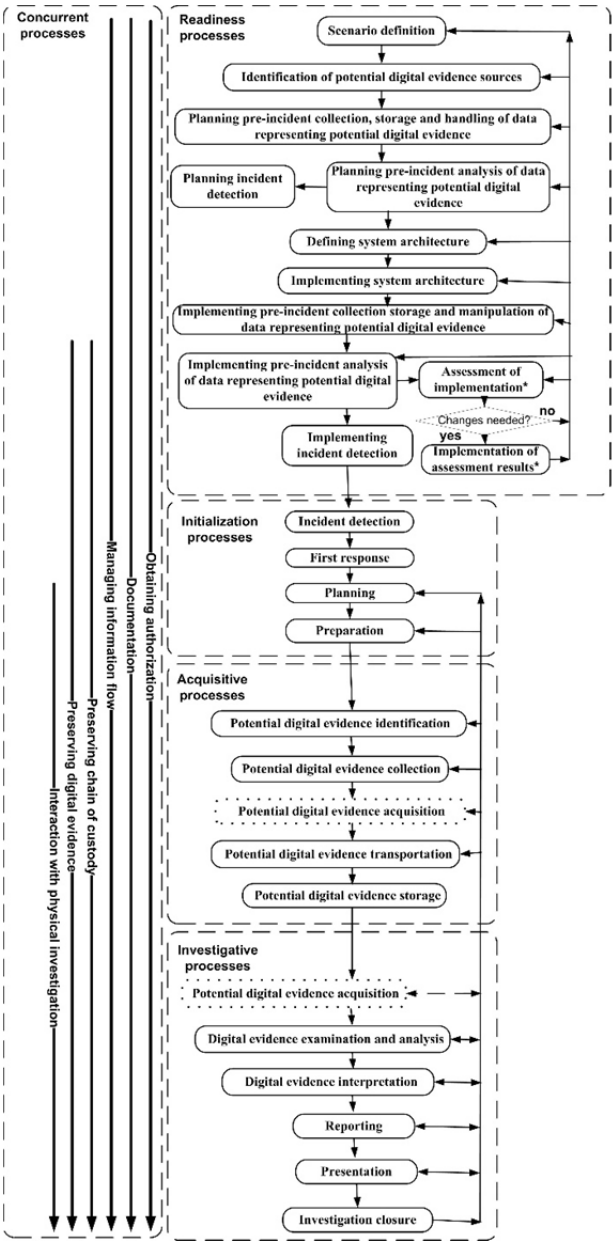

Fig. 1- Standardized digital forensic model [2]

proven methods towards the identification, collection, transportation, storage, analysis, interpretation, presentation and distribution, return and/or destruction of digital evidence derived from digital sources, while obtaining proper authorizations for all activities, properly documenting all activities, interacting with the physical investigation, preserving the evidence and the chain of custody, for the purpose of facilitating or furthering the reconstruction of events found to be incidents requiring a digital forensic investigation, whether of criminal nature or not [3].

The following section provides a brief overview of related work regarding other digital forensic investigation models.

B. Related Work on the Digital Forensic Investigation Process Models

Many digital forensic investigation process models have been proposed across the world, however, there exist numerous disparities among these process models. A few examples of these models include Reith et al. [5], The U.S. Department of Justice (DOJ) model [6], Carrier and Spafford [7], Mandia et al. [8], Beebe and Clark [9], Cuardhuáin [10], Casey and Rose [11], and Cohen [12]. Disparities in these models pertain to the number of processes included, the scope of models, and the scope of similarly-named processes within different models, the hierarchy levels and even concepts applied to the construction of the model (i.e. some of the models are based on the physical crime investigation processes). Due to space constraints the details on this research will not be presented here.

To address this issue the authors have contributed to a process within ISO, with the aim to standardize the digital forensic investigation process model [2].

The following section provides an overview of related ISO27053:2015 international standard [2].

C. Standardized Digital Forensic Investigation Process: A Comprehensive and Harmonized Digital Forensic Investigation Process

The ISO/IEC 27043:2015 international standard [2] was published in March 2015. It defines an idealised model for the digital forensic investigation process. The model is intended to be used for various types of digital forensics, from post-mortem to cloud forensics and also in various investigation scenarios. These scenarios include (but are not limited to) criminal and civil cyber-crime cases, and corporate digital forensic investigations. Security incidents that are investigated can be criminal in nature or not. They can also range from serious cyber-attacks on critical infrastructure information systems (such as ports) to investigations into the unauthorised use of a company's IT resources for personal matters (such as use of the company's phone). Due to space constraints the full standardised investigative process will not be presented here. Related work can be found in [2, 3]. For reference the full model schema is shown in Fig. 1.

The following chapter presents the proposed prototype.

III. PROTOTYPE FOR GUIDANCE AND IMPLEMENTATION OF A STANDARDIZED DIGITAL FORENSIC INVESTIGATION PROCESS

This section explains the prototype, its potential use and benefits.

The prototype is in the form of a software application which has two main functionalities. The first main functionality would be to act as an expert system that can be used for guidance and training of novice investigators. The second main functionality would be to enable the implementation of the investigation process while reliably logging all actions in a digital forensic fashion. Another goal in designing the prototype is to maximize and encourage collaboration between different organizations by allowing them to work together on a case from any location.

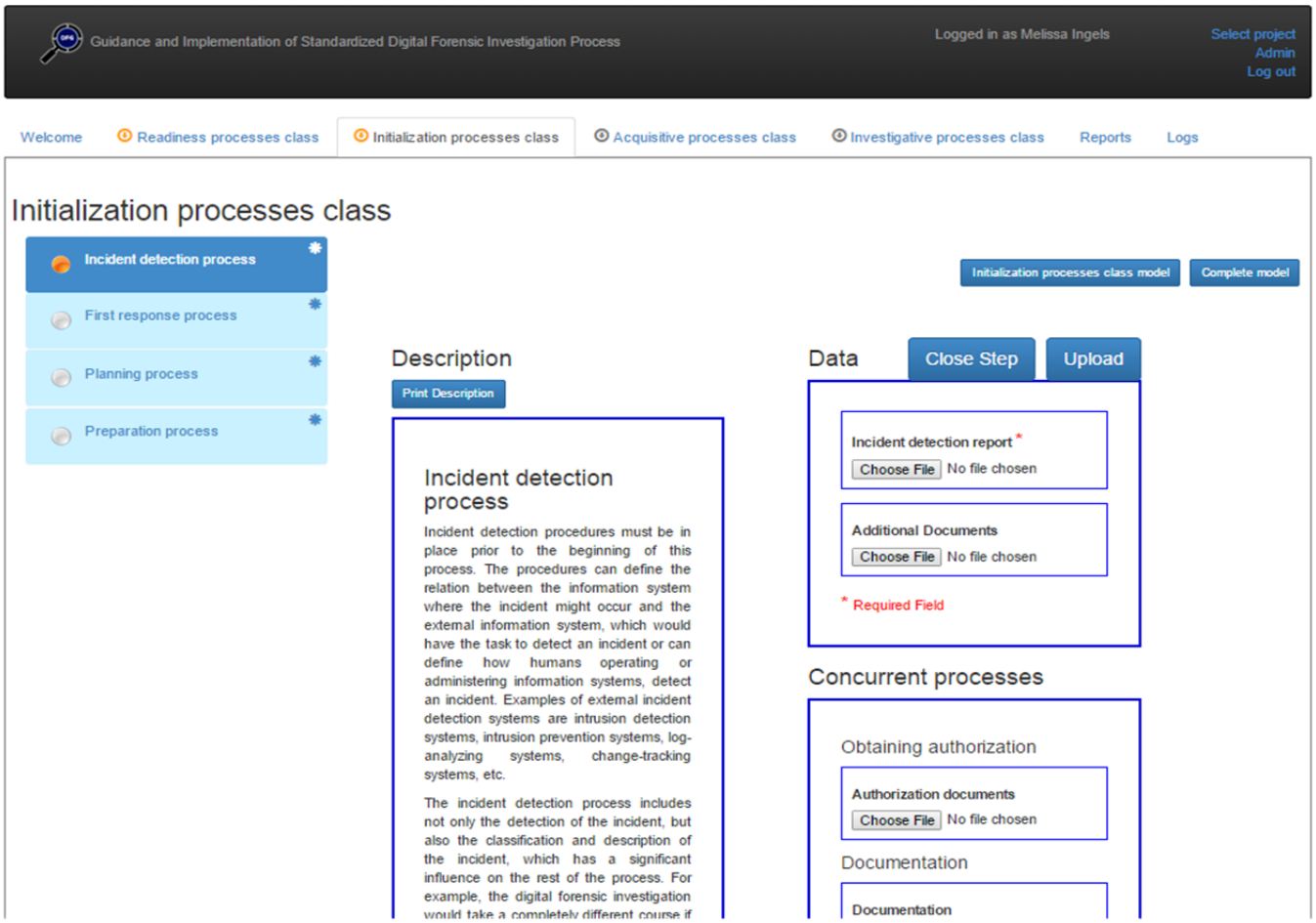

Fig. 2 - Screenshot of the Graphical User Interface

There is currently a need for investigators to be trained in the use of digital forensic investigation processes as stated by [13] that "Despite criticisms, the reality today is that investigators are currently using a high level of automation in investigations, and newer, or uninterested, investigators who are trained on a specific tool may be unable or unsure how to do investigations without the use of automation contrary to the view that every investigator [they] should have a solid, non-tool-centric knowledge of the investigation process. Whether this lack of knowledge comes from a lack of training, time or funding, it has real implications on the quality of investigations being conducted." The prototype would provide training and guidance for new investigators during an investigation, the prototype addresses the lack of time or money by offering the software as a Software as a Service (SaaS). The authors believe this will result in higher quality of investigations.

For illustration purposes only, Fig. 2 presents a screenshot of the Graphical User Interface showing the initialization processes class, specifically the incident detection process. It is intended that one can follow the processes, as per the standardized process model [2]. Meanwhile the software provides guidance (on the left side of the user pane) and the possibility to implement the process (on the right side of the pane). The user can freely browse the guidance on any step, however he/she will only be able to implement the steps as per the standardized process sequence.

The user can also choose to generate reports by selecting the "Reports" tab from the task bar at the top. Reports serve as proof that the process was followed by the investigation team for audit purposes.

The information system security is based on the use of cryptographic technologies in order to ensure efficient access control, confidentiality and integrity of all information.

Non-repudiation of user actions is enabled through use of digital signatures. This also enables the verification of the authenticity of actions and any associated information (files) as accessed by the user.

The following sections explain the system layout, including the system architecture, components and information system security.

A. *System Architecture*

This section gives an overview of the system architecture, with the focus on technology components used to realize the prototype (software).

Database – The database is implemented using MySQL [14] which was chosen because it is free, fast and cross-platform. MySQL includes data security layers to protect data from intruders, passwords are encrypted and rights can be set up to allow only certain access.

Platform– The platform chosen for the prototype is web-based as this allows ease of use across multiple platforms and from any location. It enables collaboration of multiple users, from multiple organizations. It also enables the provision of the software as Software as a Service (SaaS). SaaS provides better cost effectiveness for the user and it enables user to concentrate on the core activity- the digital forensic investigation.

Language and Framework– The prototype is implemented using the PHP [15] coding language and the Laravel Framework [16]. Laravel is a free, open source PHP web application framework, designed for the development of MVC (Model-View-Controller) web applications. The Laravel framework was chosen because of its MVC and REST (Representational State Transfer) capabilities, as well as its database support and available add-ons and libraries.

User management– For user management Sentry [17] is used. Sentry is an add-on to Laravel which provides configurable user management and it is interface driven. Sentry also encrypts all passwords and allows for an easy way to authenticate a user and to prevent access to pages based on the user that is logged in.

Report generator– For generating reports the tool *wkhtmltopdf* [18] is used. *wkhtmltopdf* is an open source command-line tool to render HTML into PDF using the QT Webkit [19] rendering engine.

Component communication architecture– All components (see next section) communicate using the REST architecture. REST is an architectural style which consists of Components, connectors and data elements for distributed web systems.

The next section concentrates on the functional components of the prototype.

B. Components

This section describes functional components of the prototype and their interaction. When the user enters the site, he/she will be passed through the User management and access control module where they will be authenticated and permissions will be checked. If Authentication fails the user will be asked to log in again. If login succeeds, the user will be able to choose whether they want to generate a report (passing them through the reporting module), logout or implement a step. If the user chooses to implement a step they will be able to choose whether they want to view the guidance (passing them through the guidance module) or upload data to a step (passing the data through the Digital Signature Verification module as well as the Encryption module).

User Management and Access Control module– This module is responsible for managing user authentication and access control. Access control is role-based, meaning only users with the correct roles are allowed to access certain projects, data and functionalities of the software. All users are allowed to close or reopen a step (Explained in the *Process implementation and logging module* section). Table 1 shows a comparison between the different roles and their permissions. Every role has access to generating a report for the currently logged in user and the current project. The Legal System representive and the Accused roles have access to generating reports, they do not however have permission to implement any of the steps inside any of the processes. The System overseer and System owner roles can generate reports for all users within their organisation. A user can have more than one role in the system and will have access to all of the steps that are allowed by the combined roles.

Table 1 - Comparison of user roles

	Admin	***Readiness***	***Initialization***	***Acquisitive***	***Investigative***
Root	N	Y	Y	Y	Y
System overseer	N	Y	Y	Y	Y
System owner	Y	Y	Y	Y	Y
System custodian	N	Y	N	N	N
System administrator	N	Y	N	N	N
First responder	N	N	Y	Y	N
Investigator	N	N	Y	Y	Y
Analyst	N	N	Y	Y	Y
Legal system representative	N	N	N	N	N
Accused	N	N	N	N	N

Reporting module– This module is responsible for generating reports of users' actions. The Reporting module is of crucial importance as it enables verification of following a proper standardized process and adhering to all guidelines and requirements. This module enables the creation of reports by authorized users, per project, user, concurrent process and organisation.

Process Implementation and Logging module– This module guides the user through completing the processes, it allows the user to choose a process (Readiness, Initialisation, Acquisitive, Investigative), and upload the documents for a step inside the process. From here the user can upload documents, enter data, view guidance as well as generate reports. The user can also close or reopen a step. Closing a step prevents any further data from being uploaded to the step and enables the users to continue with the next step in the process. Reopening a step will reopen all steps that were implemented after the relevant step. When reopening a step the user has to provide a reason for reopening the step. The reason can be used for audit purposes.

Guidance module – This module provides guidance to the user in terms of how the process should be implemented – though either graphical or textual advice, or both. This component is optional to the user. The guidance module is especially intended for use by novice investigators or other novice professionals involved with digital forensic investigation.

Digital Signature Verification module– When the user uploads a document (containing the data related to the current step), this module will verify that the document was signed by the user attempting to upload it. The user will have to sign this document (using the certificate generated by the User Management and Access Control module) prior to uploading it to the system. The prototype requires the user to sign the document in order to preserve integrity of documents and accountability of users, as promoted by the standard. If a document is not signed by the correct user the system will reject it and ask the user to upload a signed document. For prototype purposes verification is only done on PDF, DOCX (Word 2010) and XML files.

Encryption module– The encryption module is responsible for encryption of all textual data entered by the user as well as any files uploaded by the user. The data gets encrypted in order to preserve the integrity and confidentiality of the data. The data is encrypted in such a manner that only authorized users can access it. This module uses AES256 to encrypt the textual data and files.

The next section explains the functionality of the Admin module of the prototype.

C. *Functionality of the admin module of the prototype*

The admin module is only accessible by the system owner. The data displayed in the respective admin pages are also limited to the access the user has. The Root admin role has access to the admin section with no restrictions on what the user can view, edit, add or delete. This role is intended for the prototype owners that manage the entire system. The restriction placed on the System owner role is to protect confidentiality of the users and the integrity of the system.

Following is the explanation of the different sections inside the admin section. The explanations are written with the restrictions of the System owner role.

User section – The user section allows the currently logged in user to view, edit or disable the users that are part of his/her organisation. This section also allows the logged in user to generate a digital certificate for the users he is allowed to view.

Organisation section – This section allows the currently logged in user to view the organisation he/she is part of. It also allows the user to add or remove users from his organisation. When editing the organisation the user will be able to change the name as well as choose which other organisations are allowed to see his/her organisation's users.

Project section – This section allows the currently logged in user with appropriate access rights to add, edit or close/reopen a project. It also allows the user to add or remove users from the project.

The following section covers the usability tests and their results.

IV. EVALUATION- USABILITY TEST AND FUNCTIONAL SURVEY

In this section the author presents the results of evaluation of the proposed prototype. A usability test and survey were designed and performed to evaluate the usability of the system. A survey, referred to as the Functional survey, was further set up to evaluate whether the prototype meets the goals proposed in this paper. The latter survey also included questions aimed at improving the prototype.

The usability testing survey was based on the Software Usability Measurement Inventory (SUMI) measurement provided by SUMI [20]. The Software Usability Measurement Inventory is a rigorously tested and proven method of measuring software quality from the end user's point of view [20]. It consists of 50 statements to which the user has to reply *Agree*, *Don't Know*, or *Disagree* [20]. Answers are then used to evaluate software's quality as per method developed by SUMI [20].

The Functional survey was set up by the author and fellow students from the ICSA research group at University of Pretoria.

The testing process was designed as an assignment for students taking the Digital Forensics course at the University of Pretoria. All students were final-year students busy completing their BSc in Computer Science. The test procedure was chosen as the students are classified as novices (no practitioner experience) when it comes to digital forensic investigations. The students were requested to apply the proposed process model, with provided scenarios, and use the prototype for guidance and implementation. A total of 32 students participated in the testing, which is more than the minimum recommended number of participants as defined by SUMI [20].

The following section presents an overview of the usability testing results.

Table 2 - SUMI result summary

	Mean	***St Dev***	***Median***	***IQR***	***Min***	***Max***
Global	43.62	12.87	41.0	16.5	19	72
Efficiency	42.17	13.06	41.0	21.0	21	72
Affect	41.93	16.94	41.0	28.0	15	72
Helpfulness	46.55	13.34	44.0	18.0	21	72
Control	43.76	12.52	42.0	14.5	19	68
Learnability	49.93	14.50	55.0	22.0	19	71

A. *Usability testing results*

The usability test was conducted after the students completed the assignment using the prototype. The students were asked to fill in the survey on their experiences with the

prototype. SUMI is the only commercially available questionnaire for the assessment of the usability of software which has been developed, validated, and standardized on an international basis [20]. SUMI is a rigorously tested and proven method of measuring software quality from the user's viewpoint.

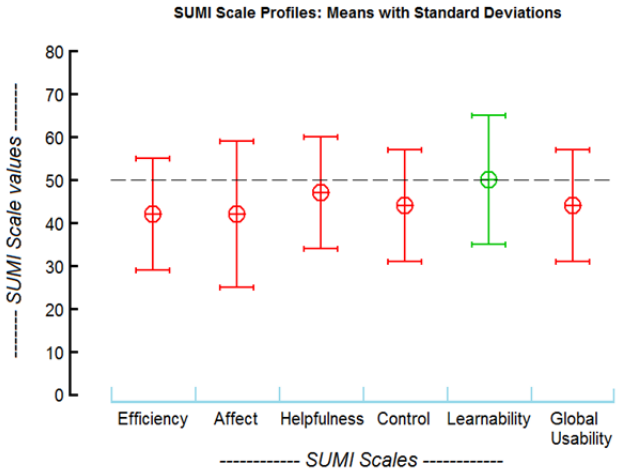

Fig. 3- SUMI scale profile

It is a consistent method for assessing the quality of use of a software product. It is backed by an extensive reference database embedded in an effective analysis and report generation tool [21]. A report was provided by the SUMI organisation. The results are divided into a global scale and 5 sub-scales, as defined by SUMI [22]:

- Efficiency – Measures the degree to which users feel that the software assists them in their work and is related to the concept of transparency
- Affect – Measures the user's general emotional reaction to the software - it may be glossed as Likeability.
- Helpfulness – Measures the degree to which the software is self-explanatory, as well as more specific considerations such as the adequacy of help facilities and documentation
- Control – measures the extent to which the user feels in control of the software, as opposed to being controlled by the software, when carrying out the task
- Learnability – measures the speed and facility with which the user feels that they have been able to master the system, or to learn how to use new features when necessary.

SUMI uses a z-score transformation to make the scales have an expected mean of 50 with a standard deviation of 10. The prototype scored a global score of 43.62. The result is within the general expected score, but the results indicate that the user interface should be improved. Table 2 shows the Mean, Standard Deviation, Median, interquartile range (IQR), minimum and maximum scores in each subscale as well as the global scale. As can be seen from Table 2, Learnability got the highest score which indicates that the prototype is relatively easy to learn and understand. Affect got the lowest score

Table 3 - Functional Survey result summary

Section	***Average rating***
Overall system rating	3
Guidance for ISO 27043	4
Understanding of ISO 27043	4
Usefulness	4
Collaboration	3
Accessibility	4
Manual usefulness	3
Guidance usefulness	3
Flow of the system	3

which indicates that the prototype might have frustrated the users. The other sub categories got a mean between 42 and 46, which indicated that they could also be slightly improved but were good overall. As can be seen by the Min and Max values, some users were very satisfied and some were not. The highest scores are usually around 72 while the lowest scores are usually around 19. The IQR values are given as a reference. Fig. 5 presents a graphical view of the means and standard deviations under each sub-scale. It can be noted that the overall mean scores are slightly below average. This indicates that the interface in general could be improved in terms of usability. However it is clear that the prototype does fulfill main functional requirements.

We analysed the user answers with regards to what they think is the best aspect of the prototype. Most users indicated that the logical outline of the software and the step-by-step guide was the best aspect. Others indicated that the design, guidance and response time were the best aspects for them. We also analysed the responses with regards to what they think should be improved. The majority of users indicated that the error messages provided should be more elaborate and that the guidance and help could be improved. Other users also indicated that there were a couple of minor bugs which need attention.

The following section presents an overview of the functional survey results.

B. Functional Survey results

The functional survey was performed after the students completed the assignment. The students were asked to complete the survey online. The questions were designed to determine whether the prototype met its goals and the general impression of the software. The authors developed the survey and the result view using HTML (HyperText Markup Language) and PHP (Hypertext Preprocessor) and used the data to generate a report. During the analysis of the functional survey, the authors calculated the average score (out of 5) for each section. The results are indicated in Table 3.

The results indicate that the manual, guidance, flow and collaboration of the prototype could be improved. Our analysis also indicated that 87% of the users used the provided guidance and 50% of the users used the provided manual (in the form of a PDF document) along with the software. The fact that only 50% of the users used the provided manual is a potential indication that the software is self-explanatory and user-friendly. Analysis of the various comments indicated that error messages should be clearer and that there are still some minor bugs, especially with the signature checking on files. Results also indicated that the guidance can be improved. The users also indicated that they think the system can be very useful and helped them to understand the flow of the ISO 27043 process model [2]. Various users also suggested that the software should be able to communicate and synchronize data with other existing forensic tools. In terms of reports the results showed that 90% of the users understood the reports and the main suggestion was to add more descriptions.

The following chapter provides discussion and critical evaluation of the proposed prototype.

V. Discussion and critical evaluation

The prototype enables one to easily follow the standardized process, which would result in higher admissibility of digital evidence and results of digital forensic investigations. Higher admissibility of digital evidence and results of digital forensic investigations would be possible. This is due to the fact that courts of law would probably be more satisfied that a standardized and formalized process was followed during a digital forensic investigation which was accepted as an international standard.

Another use of such a prototype is that it would provide for training of novice investigators. Yet another benefit is the possible improvement in efficiency and effectiveness of digital forensic investigations due to the fact that clear process guidelines are available.

These two main functionalities which provide the benefits as explained above, are acting as an expert system that can be used for guidance and training of novice investigators and enabling the implementation of the investigation process while reliably logging all actions in a digital forensic fashion.

The use of the software (prototype) would significantly aid any organization involved with digital forensic investigations to follow a standardized process and improve admissibility of digital evidence and results of investigations.

The authors proposed and implemented a well-defined architecture for the prototype and defined key functional components, while taking into consideration information systems security. A web-based platform was chosen to develop the prototype in order to cater for multiple users from multiple locations and jurisdictions, with minimal requirements for client infrastructure. Cryptography is used to ensure confidentiality and integrity of all information, as well as to ensure non-repudiation of user actions.

To summarize the evaluation of the prototype, from the usability testing results the following can be concluded: According to the SUMI scales, Learnability scored the highest overall score. This means that users quickly learned how to use the prototype and remembered it well. Helpfulness also received a high score, indicating that a lot of users found this prototype to be useful in the given scenario. The results also indicated that the logical outline of the prototype was one of the best aspects. It can also be concluded that guidance and User Interface could be improved to enable the user to use the prototype more efficiently. The users also indicated that there were a few minor software code bugs.

Based on the functional survey results it can be concluded that the users feel the prototype can be very useful to digital forensic investigators. Guidance, Understanding, Usefulness and Accessibility scored 4 out 5, which indicated that these were the best aspects to the users. The results also indicated that the digital signature checking as well as the guidance and User interface could be improved, specifically the error messages and the way the signing is handled. Some users experienced trouble with uploading signed documents.

The usability and functional surveys served as a good indication of whether the prototype is heading in the right direction. The next testing step will be to evaluate the prototype in depth on real life scenarios and for different types of digital forensic investigations.

The following section concludes the paper.

VI. Conclusion

The problem which this paper addresses is that there exists, at the time of writing this paper, no prototype or software application for guidance through, and implementation of, a standardized digital forensic investigation process model which can be used as a standardized tool. The prototype addresses the problem by acting as a tool which can help one to properly follow a standardized digital forensic investigation process. The prototype is also in the form of a SaaS application which will encourage organizations to work together and build a team of experts best suited to the relevant case.

From the evaluation testing we can conclude that the prototype can be very useful to investigators and that it could provide benefits ranging from higher admissibility of digital evidence to improving efficiency and effectiveness of digital forensic investigations. We can also conclude that the system is relatively easy to learn but does require some additional work.

The authors believe that the prototype is a significant step towards enabling implementation of a standardized digital forensic investigation process model. The prototype not only enables implementation, but also logging and non-repudiation of all user activities, with special concentration on concurrent processes, which cater for evidence integrity.

The authors now describe planned future work.

We plan to extend this prototype by improving the usability, allowing users to upload predefined XML files with keywords and compiling big sets of data into documents so the user does not have to. The authors also plan to implement the proposed changes gathered from the evaluation testing. These changes include an improved User Interface and improved

guidance. After the implementation, the authors plan to run these tests again to evaluate how well the changes were implemented. The authors also intend to do more in depth testing on real life cases and on different types of digital forensic investigations, as well as involving experienced forensic investigators in the testing process. The prototype is also in the process of being redesigned to make it more user-friendly and visually appealing.

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