Forensic Science International 344 (2023) 111601

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Technical note: A mobile collaborative workspace to assist forensic experts in disaster victim identification scenarios

Carlos Rodríguez-Domínguez [a], Ana Belén Márquez-Ruiz [b,*], José Luis Garrido [a], Kawtar Benghazi [a], Lucas González-Herrera [b], Aurora Valenzuela [b]

[a] Department of Computer Languages and Systems, ETSIIT, University of Granada, Calle Periodista Daniel Saucedo Aranda s/n, 18071 Granada, Spain
[b] Department of Forensic Medicine, Faculty of Medicine, University of Granada, Avenida de la Investigación 11, 18071 Granada, Spain

ARTICLE INFO

Article history:
Received 16 November 2022
Accepted 8 February 2023
Available online 10 February 2023

Keywords:
Disaster victim identification (DVI)
Forensic data management
Mobile systems
Collaborative applications
Real-time communication

ABSTRACT

Integrated approaches to disaster victim identification (DVI) management have led to a need for technologies to improve interaction among parties involved in post-mortem (PM) and ante-mortem (AM) data collection through better communication and coordination. Mobile Forensic Workspace© (MFW) is a collaborative mobile system that not only facilitates the systematic collection of high-quality data, but also allows DVI professionals to coordinate activities and exchange data through secure real-time communication at major disaster scenarios in accordance with security, privacy and legal protocols. MFW is adaptable to any communication format (text, voice calls, photographs, etc.) and is dynamically self-reconfigurable when connectivity problems arise. It also allows data integration and backup through secure communication channels between local and remote servers. The feasibility of the system has been demonstrated through implementation of MFW on the iOS platform for iPhone, iPod Touch and iPad terminals. A further strength of MFW is that it provides out-of-the-box support for INTERPOL DVI forms. The application of information and communication technologies for DVI was shown to be useful in improving DVI management by enhancing the quality of data collection and enabling non-Internet dependent real-time data sharing and communication.

1. Introduction

Identifying the victims of mass disasters constitutes a complex and challenging task for forensic scientists, not only because of the number of deaths and state of preservation of the human remains, but also because of the conditions in which these operations usually take place [1]. Lessig and Rothschild [2] stated that successful identification relies essentially on organization, experience, and documentation of the findings. According to the current INTERPOL DVI Guide [3], quality management of post-mortem (PM) and ante-mortem (AM) data collection is a crucial step in the disaster victim identification (DVI) process to ensure accurate, impartial and scientifically reliable findings that can withstand legal and judicial scrutiny. Poor-quality data (e.g. errors in the reproduction of original records, problems during electronic transfer, or manual entry errors) prevent matches, which may lead to false exclusion or incorrect identification [4]. In addition, there is a need to coordinate and organize DVI operations appropriately in order to avoid duplicate activities, fragmented communications, or delayed tasks [3].

With the aim of surmounting these difficulties, there have been attempts to incorporate technological advances in DVI processes. Specifically, software products have been used in recent years in operations for data collection and matching purposes [5–7]. A good example of this is KMD PlassData DVI (KMD A/S, Denmark), also known as DVI System International [5], a database application to specifically record, store, search and compare PM and AM data contained in INTERPOL DVI forms [8]. However, since collaboration is an inherent feature of forensic scenario work, technologies are also required to improve interactions among parties involved in the data collection process through better communication and coordination [9].

Accordingly, the main goals of the work reported here were: 1) to provide technological support for in-situ management of DVI information, and 2) to create a dynamic forensic workspace that allows DVI professionals to coordinate activities and exchange data through secure real-time communication at major disaster scenarios in accordance with security, privacy and legal protocols.

* Corresponding author.
E-mail address: abmarquez@ugr.es (A.B. Márquez-Ruiz).

https://doi.org/10.1016/j.forsciint.2023.111601

2. Material and methods

An iterative software engineering methodology was used to rationalize the research and development work. This methodology comprises the following stages: analysis, design, implementation and maintenance.

2.1. Analysis

In functional terms, the outcomes established for of this research were to enable forensic professionals to: 1) collect and manage PM and AM data from DVI cases; 2) share and synchronize information, even at scenarios where connectivity is limited; 3) produce reports according to Interpol DVI standardized forms; 4) manage users, work teams and roles; and 5) store collected information in centralized servers owned by official agencies.

In addition, the system proposed here needed to fulfill three quality criteria. 1) The collected data was to be associated with timestamps and authoring marks in order to maintain the chain of custody. 2) The system was to work without an Internet connection, in order to operate in offline DVI scenarios (e.g., natural disasters, terrorist attacks, etc.). 3) Users needed to be able to interact with the system via mobile devices to improve usability and allow physical movement throughout the DVI scenario.

2.2. Design and implementation

Mobile Forensic Workspace© (MFW) was designed as a shared and secure mobile, collaborative workspace. The application was designed to be installed on mobile devices (i.e., smartphones, tablets, etc.) used by professionals in order to access the workspace, and to provide automatic data backup and communication routing. Data backup secures data by versioning it and storing information snapshots that can be restored in case of failure. Communication routing allows offline operation by interconnecting the devices in a DVI scenario through Wi-Fi and Bluetooth. In case an Internet connection becomes available, the data collected most recently can also be stored on remote servers. Additionally, multiple servers can also be configured as replicas, to ensure that in case of critical failure of any server, the replicated servers will be available without loss of data.

The current version of MFW was implemented in the iOS platform, using native platform frameworks, Swift programming language and the Xcode integrated development environment. Communication routing and data backup were implemented with the BlueRose middleware-based platform [10,11], which was previously developed by the authors to overcome issues concerning communication dynamicity, multiparadigm communications, heterogeneous technologies, and real-time interactions. Given that the existence of a network infrastructure cannot be taken for granted in contexts where incident management tools are needed at DVI scenarios, Mobile Ad-hoc NETworks (MANETs) were used as a support for the mobile collaborative system.

2.3. Software maintenance and iterations

The implementation work produced five prototypes of the software, which were gradually improved in overall quality and requirement fulfillment. The prototypes were tested in simulated scenarios using iPad devices, with up to twenty forensic and police force professionals interacting at the same time. In order to better organize future maintenance operations, a versioned code repository was created. In addition, a bug reporting forum was set up to document software failures and future improvements for subsequent analysis and implementation.

3. Results and discussion

3.1. DVI data collection and management

Information management is a critical feature of the DVI process, given that the data collected will be utilized throughout the duration of the operation [3]. The origin and quality of the information collected tend to vary; moreover, data presentation formats may also vary in the form of texts, images, sketches, tables, etc. In addition, different types of text information often come into play, including texts that report measurements (meters, kilograms, etc.), dates, scannable texts (barcodes, QR-codes, etc.), and yes/no information. The MFW system is able to handle any type of PM or AM data, and enables the direct recovery and recording of data on a single form in an accurate and precise manner, in compliance with current recommendations [12]. Therefore, MFW also helps to reduce repetitive activities such as data transcription after paper-based scene data collection – a task that can be physically and mentally draining for DVI practitioners [13].

Within the workspace, a set of integrated applications are available to manage DVI data (i.e. creating, modifying, sharing, etc.), thus providing users with effective tools for cooperation. True cooperation capabilities exist in MFW because the following three basic inherent functionalities are available: communication (instant messaging or phone calls), collaboration (the simultaneous editing of information on a victim by several users), and coordination (the direct addition of footnotes to photographs shortly after being obtained). The fact that the system allows users to collaborate and manage documents via mobile platforms (smartphones or tablets) presents significant advantages over current systems of data collection and management, such as DVI System International [5], in terms of usability. Moreover, it should not be forgotten that communication between experts participating in a DVI operation is considered a central component of quality management [14], and that existing software packages have generally not been designed to facilitate this aspect of on-site operations.

3.2. User interface adaptation

Given that the system will be used under a wide range of working conditions (depending on the agency or type of emergency, e.g., natural disaster, accident, terrorist attack, etc.), the workspace has been designed to be easily adaptable by users themselves to any specific requirements. The user interface and the parameters to be included in the documents within the workspace are fully adaptable to the specific requirements of each forensic scenario without requiring modification of its internal code or further intervention by information and communication technologies (ICT) experts. Hence, the application as designed is fully reusable among different official agencies. Because the main design features are intended to facilitate collaboration among users, the application allows agencies to share information based on the same data model specifications (if needed). In addition, the application contains a mechanism for translating documents into different languages (English, Spanish, etc.) in situations that require cross-border collaboration among teams from multiple countries, in order to avoid potential communication problems and ensure that protocols are strictly adhered to [1,12]. At present, MFW has been implemented on iOS for iPhone and iPad, given that the limited range of devices available on this platform ensures a homogeneous user experience.

3.3. Using the MFW

New incident cases, identified by location, event description and date, are managed through the user interface; this allows team leaders to create a specific area to store and share all documents and

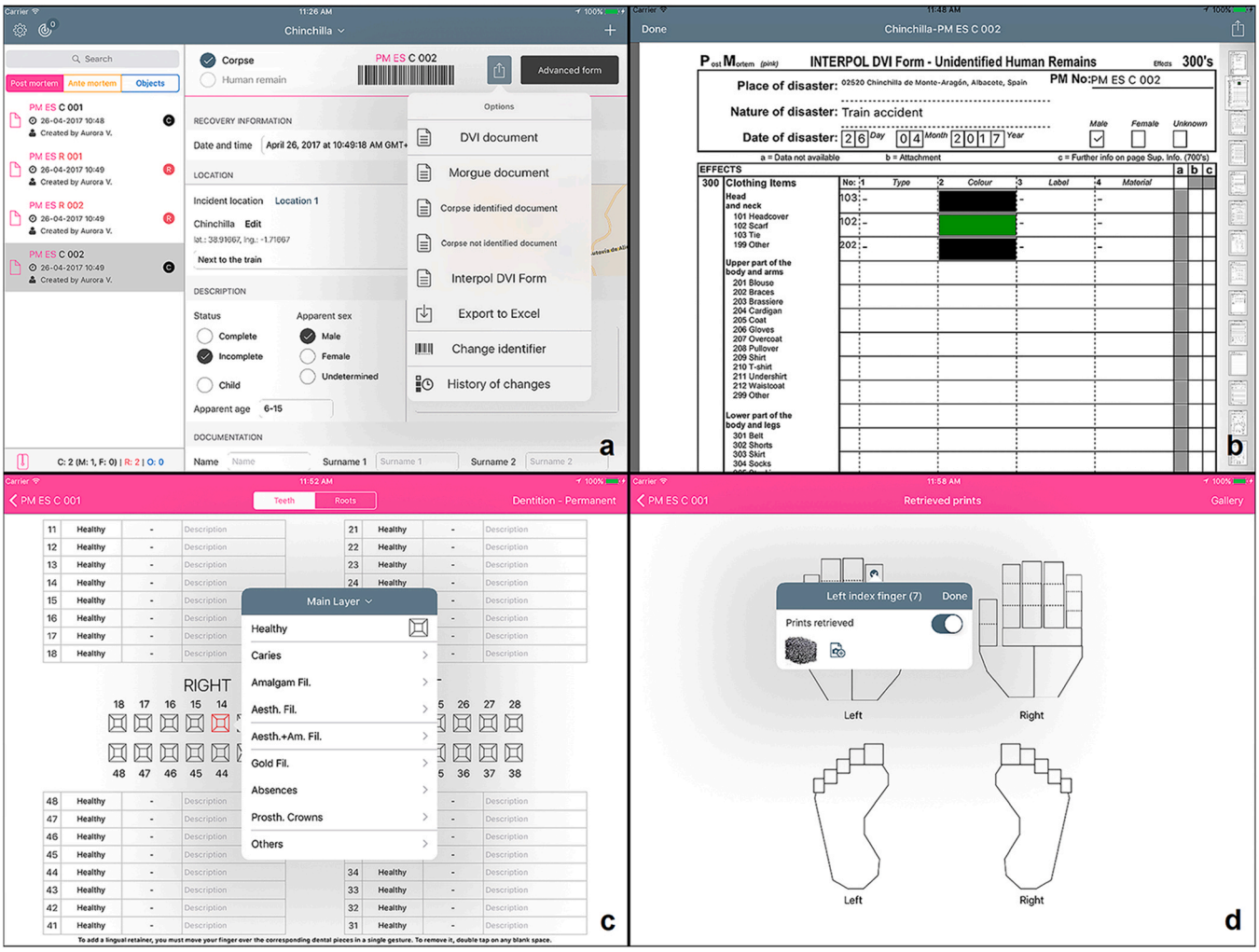

Fig. 1. Screenshots of the user interface during some task functionalities in Mobile Forensic Workspace©: (a) General information about a new case, (b) Autogenerated PM INTERPOL DVI Form, (c) Dental data collection and odontogram generation, and (d) Fingerprint and plantar footprint collection.

information concerning the victims. At present, MFW provides out-of-the-box support for both yellow AM and pink PM INTERPOL DVI forms [8], which (among additional types of information) allows the incorporation of family photos or body status sketches within their respective documents. Screenshots of the user interface during some task functions in the application are shown in Fig. 1.

All authorized users involved in an incident can receive copies of new documents, and modifications are notified automatically. When two users attempt to modify a document simultaneously, the workspace warns both users and prompts communication between them to clarify which user should input the information. Once all documents and cases have been transferred to an authorized server, the director of operations has full access to all information. As recently noted, technologies that facilitate immediate data entry into a shared system can provide greater efficiencies both within and across DVI phases [13].

3.4. Security and privacy

A successful data management system requires not only software development, but also the development of protocols, procedures and policies for data protection [13,15]. High levels of security and privacy have been achieved in MFW by incorporating the following three mechanisms. 1) Access is username- and password-dependent, and agencies can grant or deny individual permission to access or edit the documents added to the workspace, in accordance with pre-established roles or credentials assigned to each user, or in case of loss or theft of a terminal. 2) Information exchange among users is protected by an underlying communication protocol (Secure Sockets Layers, SSL), based on a highly secure algorithm to encrypt the information and ensure that any intercepted messages will not be readable or modifiable by malicious software. 3) Users will not be able to pose as other users, even after discovering username and password data, given that agencies can issue unique digital certificates for each device and incident scenario.

The platform transparently merges all collected information in real-time, notifies users of any conflicting data, and whenever an Internet connection becomes available, automatically transfers all collected data to a remote server under the control of the agency or agencies responsible for managing the emergency situation. The MFW platform thus enhances the quality of the information collected, facilitates collaboration, and avoids the duplication of records, loss of information, and the awkwardness of managing paper-based files and data.

4. Conclusions

As a technological innovation based on new methods and techniques applied to current collaborative and mobile technologies, MFW is designed to provide real-time communication and coordination for PM and AM data collection and sharing at DVI scenarios. Because the application complies with the protocols

recommended by INTERPOL and provides out-of-the-box support for INTERPOL DVI forms, it offers a useful tool to enable professionals to carry out their work in a more coordinated way and overcome the problems that arise (e.g., duplication of information, chain of custody problems, loss of evidence, etc.) when a series of actions are performed concurrently by a number of different actors. Nevertheless, it should be remembered that MFW is not designed to assist data matching in the reconciliation phase, therefore other software packages should be used for this purpose. This brief summary of MFW also points to an interesting and promising research area in the development of new workspaces for other forensic scenarios such as mass grave exhumations or domestic violence, among others.

CRediT authorship contribution statement

Carlos Rodríguez-Domínguez: Conceptualization, Formal analysis, Methodology, Software, Validation, Visualization, Writing – original draft, Writing - review & editing. **Ana Belén Márquez-Ruiz:** Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **José Luis Garrido:** Software, Validation, Visualization. **Kawtar Benghazi:** Software, Validation, Visualization. **Lucas González-Herrera:** Methodology, Validation. **Aurora Valenzuela:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Writing – original draft, Writing – review & editing.

Conflict of interest

The authors declare that they have no conflict of interest and no patent law aspects have been infringed.

Acknowledgments

The authors acknowledge the technical and professional collaboration of the Spanish Guardia Civil DVI Team in the development and implementation of the MFW prototype in simulated DVI scenarios, and thank K. Shashok for editing the manuscript. This work has been funded by a research contract between the University of Granada, Department of Forensic Medicine, and Telvent Interactiva S.A., Spain, as well as by the Spanish Ministry of Economy and Competitiveness (reference project TIN2012-38600). Funding for open access charge: University of Granada / CBUA.

References

[1] L. Cipolloni, B. Baldari, L. Besi, M. Scopetti, M. Di Sanzo, S. Ursu, V. Fineschi, Management of victims occurred in mass disaster: the experience of center Italy earthquake 2016, J. Forensic Leg. Med 62 (2019) 19–24, https://doi.org/10.1016/j.jflm.2019.01.002

[2] R. Lessig, M. Rothschild, International standards in cases of mass disaster victim identification (DVI), Forensic Sci. Med. Pathol. 8 (2012) 197–199, https://doi.org/10.1007/s12024-011-9272-3

[3] INTERPOL, Disaster Victim Identification (DVI) Guide. https://www.interpol.int/content/download/589/file/18Y1344%20E%20DVI_Guide.pdf, 2018 (accessed 20 September 2022).

[4] K. Wright, A. Mundorff, J. Chaseling, A. Forrest, C. Maguire, D.I. Crane, A new disaster victim identification management strategy targeting "near identification-threshold" cases: experiences from the Boxing Day tsunami, Forensic Sci. Int. 250 (2015) 91–97, https://doi.org/10.1016/j.forsciint.2015.03.007

[5] L.A. Torpet, D.V.I. System, International: software assisting in the Thai tsunami victim identification process, J. Forensic Odontostomatol. 23 (2005) 19–25.

[6] J.G. Clement, V. Winship, J. Ceddia, S. Al-Amad, A. Morales, A.J. Hill, New software for computer-assisted dental-data matching in disaster victim identification and long-term missing persons investigations: "DAVID Web", Forensic Sci. Int. 159 (2006) S24–S29, https://doi.org/10.1016/j.forsciint.2006.02.006

[7] S.H. Al-Amad, J.G. Clement, M.J. McCullough, A. Morales, A.J. Hill, Evaluation of two dental identification computer systems: DAVID and WinID3, J. Forensic Odontostomatol. 25 (2007) 23–29.

[8] INTERPOL, Disaster Victim Identification Forms. https://www.interpol.int/How-we-work/Forensics/Disaster-Victim-Identification-DVI, 2018 (accessed 20 September 2022).

[9] E. Villanueva, C. Rodríguez-Domínguez, K. Benghazi, J.L. Garrido, A. Valenzuela, Applying information technology to forensic sciences, Int. J. Leg. Med 126 (2012) S1–S4, https://doi.org/10.1007/s00414-012-0708-4

[10] C. Rodríguez-Domínguez, T. Ruiz-López, K. Benghazi, J.L. Garrido, Designing a middleware-based framework to support multiparadigm communications in ubiquitous systems, in: P. Novais, K. Hallenborg, D. Tapia, J. Rodríguez (Eds.), Ambient Intelligence - Software and Applications. Advances in Intelligent and Soft Computing, vol. 153, Springer, Berlin, Heidelberg, 2012, pp. 163–170. https://doi.org/10.1007/978–3-642–28783-1_20.

[11] C. Rodríguez-Domínguez, K. Benghazi, M. Noguera, J.L. Garrido, M.L. Rodríguez, T. Ruiz-López, A communication model to integrate the request-response and the publish-subscribe paradigms into ubiquitous systems, J. Sens. 12 (2012) 7648–7668, https://doi.org/10.3390/s120607648

[12] D. Sweet, INTERPOL DVI best-practice standards-an overview, Forensic Sci. Int. 201 (2010) 18–21, https://doi.org/10.1016/j.forsciint.2010.02.031

[13] D. Lovell, K. Vella, D. Muñoz, M. McKague, M. Brereton, P. Ellis, Exploring technologies to better link physical evidence and digital information for disaster victim identification, Forensic Sci. Res 7 (2022) 467–483, https://doi.org/10.1080/20961790.2021.2023418

[14] A.W. Lake, H. James, J.W. Berketa, Disaster victim identification: quality management from an odontology perspective, Forensic Sci. Med. Pathol. 8 (2012) 157–163, https://doi.org/10.1007/s12024-011-9286-x

[15] U. Hofmeister, S.S. Martin, C. Villalobos, J. Padilla, O. Finegan, The ICRC AM/PM Database: challenges in forensic data management in the humanitarian sphere, Forensic Sci. Int. 279 (2017) 1–7, https://doi.org/10.1016/j.forsciint.2017.07.022