RESULTS OF THE FASTID PROJECT

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Abstract

The article presents the FASTID project to develop a database system to support international police cooperation to identify missing persons, unidentified bodies and persons unable to identify themselves both following disasters and for policing outside of disasters.

Keywords: disaster victim identification, missing persons, unidentified bodies, persons unable to identify themselves, police.

PROJECT BACKGROUND INFORMATION

The INTERPOL General Assembly meeting in 2005 adopted a resolution calling for the creation of an international missing person and unidentified bodies MP/UB database (AG-2005-RES-07).

International police cooperation to identify disaster victims is supported by INTERPOL's Disaster Victim Identification (DVI) Ante-Mortem (AM) and Post-Mortem (PM) forms. These forms have been developed and periodically updated by the INTERPOL DVI Steering Group in coordination with the DVI Standing Committee. The AM and PM paper forms are each seventeen A4 sides long, including ninety two separate numbered rows for which multiple amounts of information is also often requested. Experience during the Tsunami in South East Asia in 2004 confirmed however that despite the good practice presented in the INTERPOL DVI (AM and PM) forms the international community was ill prepared to organise and share information for DVI. During the disaster, cooperation was planned on site ad-hoc with all of the challenges caused by different operational methodologies, training and even duplication, through national DVI teams focussing on identifying their own nationals. In addition, although the international police community has the possibility to issue Yellow Notices (missing persons and persons unable to identify themselves) and Black Notices (unidentified bodies) there is no automatic system to compare the Notices and the Notices in themselves do not collect the detailed information good practice and often national legal rules require for a positive MP/UB reconciliation. INTERPOL has 190 member countries. If an international MP/UB database was available through INTERPOL, officers and other experts could be trained to use it which would offer the possibility to increase international police cooperation both during disasters and for operational policing outside of disasters.

The FASTID project ran from April 2010 to March 2013. The partners in the project were: The International Criminal Police Organization – INTERPOL, the German "Bundeskriminalamt" (BKA), Plass Data Software A/S, University of Dundee, the Fraunhofer-Gesellschaft (IOSB Karlsruhe and IGD Darmstadt) and Crabbe Consulting Ltd.

GOALS

1) Development of a prototype database system to support international police cooperation to identify missing persons, unidentified bodies and persons unable to identify themselves both following disasters and for operational policing outside of disasters.
2) Integration of the system within the operational environment of INTERPOL in Lyon, France as a prototype.
3) Extension of DNA and mtDNA matching techniques and investigation of the potential of "Image" matching techniques.
4) Development of explanatory and training material to support and encourage global common operational methodologies for identification tasks.
5) Testing and evaluation of the system, including INTERPOL member country volunteers.

METHODS USED

The project was structured in a classical way for research and development following the phases of establishing user requirements, architecture and specification development, module development, integration, testing and evaluation.

The starting point of the project was Plass Data's Disaster Victim Identification (DVI) System International commercial software. In 2005 the software was used in the centre for the Tsunami Victim Identification in Thailand. The software renders the INTERPOL DVI (AM and PM) forms. The programme was developed in Delphi and data is stored in a Microsoft SQL database. Matching of missing persons against dead bodies is possible based on two primary identifies: dental data and DNA, based on official genetic instructions for full and half band matching – direct line. It is not possible to search against the third primary identifier fingerprints but it is possible to search against secondary identifiers based on the textual information saved in the forms, such as height and weight. The only factor which limits the number of simultaneous users in the DVI System International software is the network and server but all inputted data can be viewed by all users.

A number of developments were required to meet INTERPOL's requirements, particularly with regards to: fulfilment of security and legal restrictions, global access, compatibility with existing system infrastructure and the inclusion of functions connected with the issuing of Yellow and Black Notices. More investigative research was also carried out with the goal of extending matching capabilities in the areas of the DNA, mtDNA and "Images". This paper will not cover the investigative work on DNA and mtDNA in any detail.

Overall architecture

A Microsoft Silverlight Rich Internet Application (RIA) was chosen as a basis to develop the core of the MP/UB prototype. The benefits of this technology include: an interactive user interface for validation and formatting, fast interface response times, common user interface behaviours and the ability to work online and offline. Further advantages through the utilisation of Web technology are instant deployment, cross-platform availability, the use of progressive downloading for retrieving content and data, the magazine-like layout of Web pages and leveraging widely adopted Internet standards. An overview of the architecture of the MP/UB prototype installed at INTERPOL is provided in Fig. 1

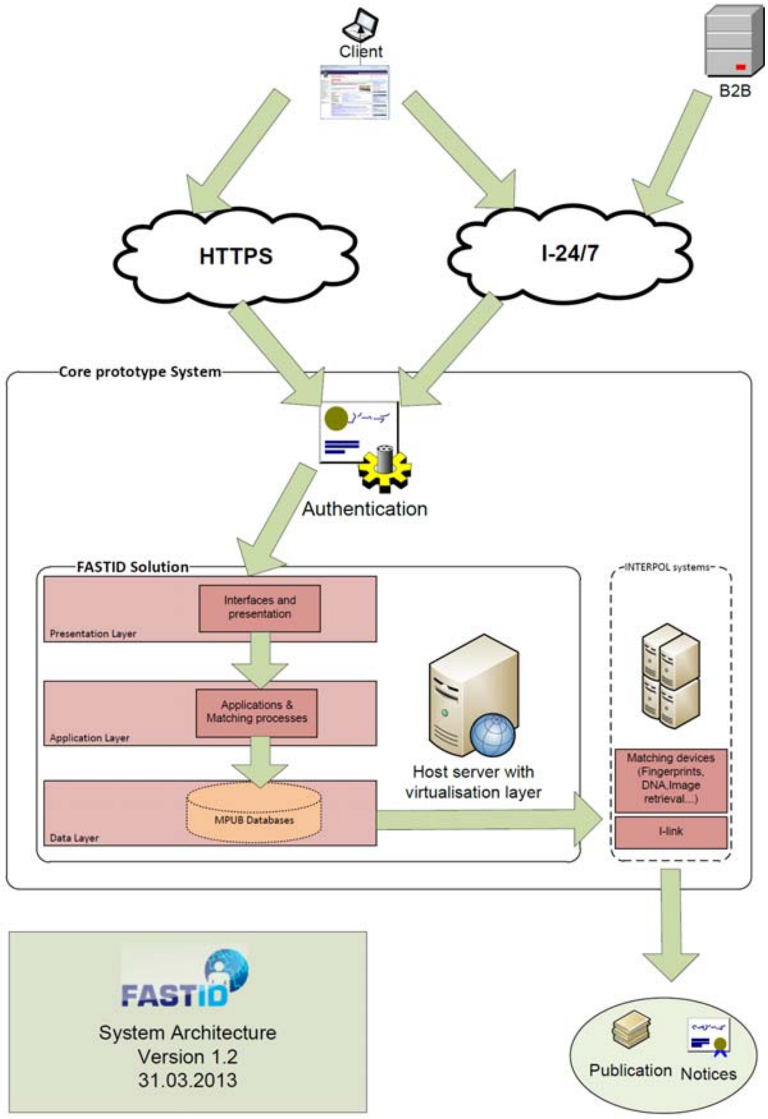

Fig. 1 FASTID Architecture

Authentication and permission management to the MP/UB system is provided by INSYST, INTERPOL's authentication system for users. I-24/7 is a secure network linking all INTERPOL member countries and giving access to INTERPOL's databases. The **FASTID Solution** contains the core services. A B2B services component is responsible for responding to incoming B2B requests from external clients through WCF-WS (Windows Communication Foundation Web Services) in the central Presentation layer, and to emit events and queries to other external services, e.g. AFIS (Automated Fingerprints Identification System), "Image" matching and I-link (a dynamic web application that allows officers in member countries to manage their data directly, and standardizes the format of the data exchanged) file updates. The front end **Silverlight Client** is distributed to each client workstation and handles the Presentation Layer. The Silverlight client exchanges data with the FASTID Solution through WCF RIA Services. If the Silverlight Client is installed locally on the client, it serves as an Offline client as well, enabling the user to collect data even if disconnected from the FASTID Solution. The Files are then saved locally as XML files until connection is re-established and an upload can take place.

"Image matching" techniques to aid MP/UB reconciliation investigated

Image matching 1: Tattoos and other body modifications

In current biometric-based identification systems, tattoos and other body modifications have shown to provide a useful source of information. For tattoos, the ANSI/NIST-ITL 1-2000 standard defines eight classes: human, animal, plant, flags, objects, abstract, symbols and other [1]. However, the matching based on manually assigned class labels is subjective, time-consuming and many tattoos do not fit in just one category. In contrast, within the FASTID project, we showed how recent advances in content-based image retrieval can be utilized to build up a large-scale tattoo image retrieval system. Its advantage is that every tattoo can be regarded as a separate class making it possible to distinguish for example different dragon tattoos based on their different visual appearance. While local feature-based similarities [2] of tattoo images achieved excellent retrieval accuracy, scalability to large image databases was addressed with the popular bag-of-words model and inverted files [3]. As opposed to [4], to counter the loss of performance due to quantization [5] in the bag-of-words model, we did not use ensemble techniques, but Hamming Embedding and Weak Geometry Consistency extensions [6].

Image matching 2: Comparison of AM and early-PM facial images

While face recognition works well for images taken under controlled conditions, face recognition in uncontrolled conditions is an active research area [7], [8]. There are challenges to cope with several influences. In the application of MP/UB the main challenges are quantity and quality for both AM and PM images. Available AM image sources cover passport photographs and private photographs taken at various events under uncontrolled conditions. Often the images are older, and the depicted person changed appearance by means of ageing, gaining or losing weight. The poses are often non-frontal and facial expressions are not neutral, e.g. if the person is smiling. The number of PM images is limited. DVI personnel are trained to acquire at least 2 images: one frontal image and one profile image. There are no restrictions on the illumination or camera hardware and settings to use. There are many PM effects that can be observed, e.g. missing blood pressure, relaxed muscles, changes in colour, livor mortis, depending on pose of dead body, development of gas within tissue (bloating), decomposition, destroyed or missing tissue. No suitable research databases of AM and PM images were identified for this research as the use of face images is subject to legal and ethical restrictions with respect to privacy protection and missing or dead persons are not able to give their consent to use their face images.

The main challenge was therefore to identify face recognition approaches which yield potential for modeling large variations. The Fisherfaces (PCA/LDA) family [9] of face recognition algorithms optimizes the ratio between intra-class and inter-class variations, e.g. given an adequate training dataset the feature space is modeled such that subject-specific variances can be tolerated while the variation between different subjects remains sufficient for discrimination. Recent advances in this area such as the LBLDA [10] approach showed promising results in challenging experiments. For the discussed project the LBLDA approach was chosen to be trained and used as feature extraction algorithm. Furthermore for the integration tasks a fusion scheme was applied that integrates multiple feature vectors of a single subject to boost subject specific information. The work is based on the assumption, that, given a sufficiently large dataset of subjects, a subject-specific location in the subspace can be modeled such that subjects can be distinguished given large variations. One of the challenges was also to preprocess the images appropriately such that the face region is well aligned, sized and undistorted such that the extracted features are stable.

Image matching 3: Identification of human skeletal remains using face recognition software (FRS) and craniofacial reconstruction (CFR) and superimposition (CFS).

The process includes the production of a CFR from an unknown skull, which is then compared with a MP/UB database of facial images using automated software. This software must be based on facial proportions rather than specific facial features or texture details, so as to produce inclusive rather than exclusive results (with high numbers of false positives rather than high numbers of false negatives). The resulting collection of possible matches is then further analysed using CFS to produce single or multiple possible matches that can then be checked using one or more of the primary identifiers (DNA, dental, fingerprint).

The most appropriate face recognition system for this task was considered to be the Viola Jones algorithm [11] [12] using an Active Shape Model (ASM). ASMs were incorporated into a graphical user interface (GUI) which locates the face within the input image (frontal image of CFR) and annotates outline of facial features and jawline with 76 points. Three features were added to GUI; the ability to manually adjust the position of individual points using a mouse pointer, a weighting scale feature, so that low accuracy CFR features could be made less important in the comparison, and a “compare” feature, which automatically ranked a selected folder of face images in order of similarity to the input image in terms of Euclidian/Mahlanobis distances from centroid (nasal tip).

In order to implement and train face recognition comparison for face images and craniofacial reconstruction (CFR) images two independent datasets for development and testing were required. AM/PM simulated datasets were developed from a UNIVDUN collection of 3D face scans (to simulate craniofacial reconstructions) and related face photographs (to simulate MP/UB images) of living subjects, and a further broad collection of face images were sourced from portrait books, research-access face databases and internet sources. A database of 6377 facial photographs was collected, along with 5 simulated PM subjects and related face images and laser scans.

User training and assistance

Operational commonality is essential for working in international cross-border identification. Previous large-scale disasters have identified cultural and linguistic issues in data recording [13] [14], particularly on the INTERPOL DVI forms sections C and D for personal effects and physical characteristics. An evaluation form was completed by 63 international MP/UB/DVI practitioners from 24 countries to assess and understand current issues associated with the interpretation and use of the existing recording forms. It was found that linguistic issues were a predominant issue in comparing and exchanging information, followed by the layout-of the forms, lack of instructions to complete the forms and absence of cultural and religious considerations. The input formed the basis for the development of guidance and visual aides to facilitate recording of personal effects and physical characteristics on both the MP/UB system and the hardcopy forms. Image catalogues were developed and implemented in the MP/UB/DVI system to assist with terminology and automated completion of data fields.

The input of international MP/UB/DVI practitioners in combination with the guidance and aides formed the foundation for a full online training programme. An intuitive virtual environment was developed to train international officers to understand the basic principles of data collection in DVI and MP/UB investigations and practical interactive exercises to facilitate data recording on the INTERPOL C and D forms. The training programme, built around a virtual morgue, consists of 4 modules: general knowledge of DVI/MP/UB protocols, ante-mortem data collection, post-mortem data collection and evaluation. Training material is comprised of a number of media including slideshow presentations, real-time chat support facilities for participants, virtual ‘bodies’ to practice post-mortem data recording, interactive exercises to learn relevant terminology and guidance documents with additional instructions to complete the INTERPOL DVI forms.

TEST AND EVALUATION

Overall test approach

There were three main locations for running the categories of tests: at partner premises for individual module testing; on a Microsoft “private cloud” provided by Plass Data; and on an INTERPOL hosted platform in Lyon, France, following integration of FASTID modules with INTERPOL external systems. The cloud solution outside of INTERPOL premises was chosen as it allowed flexible user access and regular prototype system updates during the testing. The INSYST test platform environment can only be accessed from INTERPOL’s premises, so a more limited user evaluation of the INTERPOL hosted platform was foreseen. The cloud solution was available for testing from April 2012 with core elements of the system and further functionalities were added progressively to include all of those developed in the project apart from the connection to INTERPOL external systems. The consortium's positive assessment of the results from testing on the "private cloud" between April and November 2012 enabled the testing of the prototype system on the INTERPOL hosted platform. Once the prototype system was installed at INTERPOL in November 2012, the system updates needed to be made physically on-site because of INTERPOL rules regarding security. At this location the functionalities tested in the "private cloud" were available for testing together with the following additional functionalities: authentication (INSYST), integration with other INTERPOL systems (AFIS for submitting fingerprints; I-link for the production of Yellow Notices). Emphasis was given to testing the functionalities not already tested or not being available on the "private cloud". From mid-February 2013 all additional functions were made fully available for testing.

The tests were carried out by the consortium partners and volunteers from INTERPOL member countries. Only officials designated by INTERPOL member countries which officially confirmed their participation in the test phase through their National Central Bureaus (NCB) which included the signing of a None Disclosure Agreement (NDA) were eligible as volunteer testers. The FASTID Consortium partners were very pleased to be able to count on 21 countries (1 African, 2 American, 3 Asian, 13 European, 2 Middle Eastern and 1 Oceania) and 94 testers which ran tests on the system with police officers, pathologists and other experts. This is the greatest number of countries ever involved in the testing of a prototype system at INTERPOL. Videos, written explanations, tutorials, on-site and virtual training and a help desk were offered in order to prepare and train the testers. The tests between April 2012 and March 2013 were divided into 3 Phases which coincided with the completion of development and integration of the functionalities developed in the project. The technical prerequisites for testing both on the cloud solution and on the INTERPOL hosted platform were a computer connected to the internet with the following configuration: Microsoft Windows XP / Vista or Seven; Microsoft Internet Explorer 8 / 9 or Firefox 5 / 6; and Microsoft Silverlight 5. In addition, an I-24/7 account was required by testers for the INTERPOL hosted platform solution.

The volunteer testers were provided with "operational" test cases with specific MP/UB or DVI contexts. These test cases were built to help the testers use the system by staying as close as possible to what they would do in real life. Testers were also given some tasks focused very much on a specific aspect of the system e.g. matching with the dental or DNA modules and integration of the "Image" matching module. Testers were also invited to test the system on their own without test cases and general user feedback on their overall user experience and any recommendations were requested. The project tracker tool "JIRA" from the company Atlassian was used to register and track the fixing of "bugs". In Test Phase 1, for example, the test cases were all related to a hypothetical disaster. Testers were invited to join the Disaster Container that was related to that event and to create the files related to the test cases that they had in their test book. The tasks were different for all testers in order to increase coverage. The tasks were split into three subsections: AM files, PM files and PUI-related tasks. The tasks sent to testers for this specific test period covered: body sketches; catalogues (clothes, personal effects and jewelry); daily work in the MP/UB part of the system (creation, edition and deletion of files…); daily work in the DVI part of the system (requesting access to a disaster container, creation, edition and deletion of files…); and pushing files from the MP/UB part of the system to a disaster container. The test cases included photographs, specific information about the missing persons and unidentified bodies found (height, weight, names, addresses…), car plates, information about the circumstances of disappearance and dental data.

Test Phases 2 and 3 aimed at evaluating the changes made to the application following previously reported bugs and at testing (or retesting) the increased functionalities as they became available such as matching with DNA, mtDNA, fingerprints and images. In addition, an international desktop exercise was organised with 11 countries to test and evaluate the virtual training programme.

Specific "Image matching" tests and evaluation

Image matching 1: tattoos and other body modifications

Departing from general practice, we did not synthetically generate query images from database images by applying transformations. Instead, a special set of tattoo images was gathered [15] which consists of 417 tattoos with two images each showing a variety of challenging real-world transformations: large scale and certain viewpoint differences, a lot of background clutter, different stadiums of tattooing process, etc. The first views of the 417 image pairs were used as query images and the second half served as database images, adding additional tattoo datasets as distractors. Given a query image, the algorithm operating on a standard desktop hardware retrieves corresponding images within a matter of seconds searching in a database of more than 300,000 images of tattoos and other body modifications. See [15], [16] for details on the various experiments.

Image matching 2: comparison of AM and early-PM facial images

The evaluation of the face identification module was carried out on a dataset specially acquired for simulating early PM effects. The acquired dataset consists of several images of 8 different subjects taken under uncontrolled conditions. Some images were taken in usual poses as AM images, for each person a number of 'simulated PM' images in unusual poses such as lying on the floor with relaxed facial expression etc. have been taken as well. The images have been taken as input for a feature extraction algorithm. The feature vectors for each person have then been fused into a single feature vector in order to extract reliable information from the set of available features.

Image matching 3: Identification of human skeletal remains with FRS, CFR and CFS

A small set of data (10 subjects) was used, taken from a donated collection of AM face images and PM 3D digital skull models (from laser scans) provided by the University of Tennessee, USA which had agreed to its use by UNIVDUN for craniofacial identification research. The WP6 evaluation phase included the addition of this AM data to a smaller set (130) of the simulated MP/UB dataset (limited in relation to age, ethnic group, gender and style) and the utilization of CFR images produced from the relevant 3D skull models. In this way five 3D surface laser scans of skulls with accompanying ante-mortem facial photographs were utilised and compared to a white male database of 143 frontal passport-style images for the final blind test phase. Each CFR view was compared to the MP/UB database using the face recognition software, which ranked each face from the database as a match to the CFR.

RESULTS

Overall results

During the three Test Phases a total of 264 "bugs" were reported, 102 improvements proposed and 50 new features requested. Of the 264 bugs, 258 were resolved and closed. Of the 6 "bugs" that are open / in progress 2 are considered minor and of the other 4, two are connected with the technical infrastructure and are not expected to be problems within a production environment and two are related to DNA matching and the issues are awaiting a decision by INTERPOL as to whether to support specific features.

The system was successfully integrated with a test platform to validate the possibility to access it through INTERPOL's INSYST portal. The system was also integrated with INTERPOL's I-link system to request fingerprint matches and to provide data for the issuing of Yellow Notices. (The issuing of Black Notices is dependent on the completion of a further INTERPOL IT project).

A comprehensive set of user roles and connected rights have been implemented reflecting the breadth of users foreseen to access the system which include (as none exhaustive examples): INTERPOL as Super User, Agency Administrators (from each of INTERPOL's 190 member countries); multi-role users (e.g. individual police officers); medical experts; and odontologists. Separate working environments are proved for international police cooperation for disasters ("DVI Container") and for operational policing outside of disasters ("MP/UB Container"). Following INTERPOL requirements different viewing and editing rules apply to the two different environments. Within the MP/UB environment for example, a country may restrict specific countries from viewing a particular file(s). The full identification workflow has been implemented. The identification workflow covers all the steps involved in identifying a missing person, connecting body parts or handling AM, PM or PUI duplicates; starting with the assumed identity of the two files, file disclosure handling, the comparison report, and the acceptance of the identification report. Users can create AM, PM and PUI files. The format of the files is based upon INTERPOL's DVI (AM and PM) forms together with additional requirements regarding Yellow Notices (missing persons and persons unable to identify themselves) and Black Notices (unidentified bodies).

Three different types of textual searches are available to the user: quick searches, advanced searches and full text searches. A quick search is a simple search request based on a limited list of criteria concerning the physical description of the person (e.g. weight, height, build, hair, sex, age etc). The search produces a list showing the number of "hits" and on what pages the hits were found. An advanced search is a query with a sentence built by different chosen items and a list of fields proposed by the user. The full search is a full text search engine, usable on the fields dedicated to the free text (e.g. Section G of the Forms). Filtering is offered as a sub-functionality of searching enabling the user to filter the results from the initial search process.

The system provides for different types of Deoxyribonucleic acid (DNA) matching, but in general three kinds of DNA matching possibilities are considered: AM versus PM, AM versus PUI, and Blind Match. The system performs direct comparisons and family comparisons for targeted queries and mass comparisons (blind searches) for Short Tandem Repeat (STR) DNA. The system also allows for the storage and comparison of Mitochondrial Deoxyribonucleic acid (mtDNA) from the hypervariable segments I and II (HVSI and HVSII) regions for a set of categories. The system uses the INTERPOL DNA exchange format.
The system provides for dental matching by comparing all dental data in AM and PM or PUI files. The matching score is calculated from the different matching properties of the dental codes on each tooth and the uniqueness within the container population. There is currently no agreed INTERPOL standard format for dental data. The system supports the Fédération Dentaire Internationale (FDI), Universal or Haderup notation systems.

The system provides for fingerprint matching by sending a fingerprint match request to INTERPOL's AFIS system. The files must be compliant with the (American National standards Institute - National Institute of Standards and Technology) ANSI-NIST standard. The fingerprints are then compared with all known fingerprints in the AFIS system. At present, the user then receives an E-mail notification of the result of the fingerprint search. The use of image catalogues integrated in the system demonstrated a decrease in linguistic ambiguities during practical tests with international, multi-lingual practitioners.

Specific "Image matching" results

Image matching 1: tattoos and other body modifications results

See [15], [16] for details on the various results. The local feature approach showed to be essential when comparing images of tattoos since the images often show tattoos in different stadiums of tattooing and tattoos are often extended or modified over time. The most difficult transformations impairing the recognition performance turned out to be extreme changes of the viewing angle as often observed for large tattoos on arms and too different object distances leading the close-up images to show details such as pores and hairs which are not visible from distant views. Due to legal and ethical issues, the module could not be tested on real AM / PM case data within the project. However, initial tests with images of clothing and personal items carried along such as backpacks or bags showed that the identification could also be supported by comparing other images with characteristic patterns.

Image matching 2: comparison of AM and early-PM facial results

The dataset used for training was small and did not contain real PM images. Therefore, the expectations were limited. Nevertheless in another experiment using the ATT faces database [17] it could be demonstrated that the fusion scheme helps to increase the recognition rates significantly. The recognition rates are comparable with the 'unsupervised' experiment in the LFW challenge [8]. In order to establish a meaningful performance estimation, the experiments including training and evaluation need to be repeated with an increased database size. The research in this area is ongoing.

Image matching 3: Identification of human skeletal remains with FRS, CFR and CFS

In the final blind test phase three of the five targets were ranked in the top 20% of the MP/UB database matches in frontal view. The two CFRs that were not correctly matched to the target in the top 20% by the face recognition software had significant AM image problems, which would be removed if passport regulations were followed in relation to image quality. Craniofacial Superimposition further placed two targets into the top 10% of matches and incorrectly excluded the other edentulous target. The results suggest that erroneous matches were made where the AM image did not conform to passport regulations and CFS exclusions were made where the skull was edentulous. When these criteria were adhered to the face recognition software ranked the target in the top 20% of the MP/UB database and CFS further excluded half of the possible matches to rank the target in the top 10% of the database. Guidelines for this craniofacial identification process were also suggested.

Prototype Implementation

INTERPOL has prepared an MP/UB Implementation Project to implement the FASTID prototype at a production-level scale, without image matching (after 1 year) and adding further technical enhancements e.g. image matching techniques 1 and 3 described in this paper and interfacing with INTERPOL's own DNA database (after 2 years). At the time of writing funding for the project is being sourced.

CONCLUSIONS

An advanced prototype MP/UB and PUI system with a virtual training programme to support international police cooperation both following disasters and for operational policing outside of disasters was delivered by the project. The system provides matching capabilities for all three primary identifiers and further secondary identifiers. The virtual training programme and features within the system offer the potential for greater commonality of approach based on good practice. It would take one year to implement the prototype at the production level scale making it available to INTERPOL's 190 member countries, increasing international police cooperation both during disasters and for operational policing outside of disasters for MP/UB and PUI.

COLLATERAL INFORMATION

The research leading to these results has received funding from the European Commission's 7th Framework Programme under grant agreement no. 242339. AM and PM training and testing data is required to advance certain image matching techniques which is presently not available because of legal and ethical rules. The situation could be improved by: establishing a legal basis for exchange of data between institutions; enhancing the data acquisition process; and providing a legal basis to store data on solved cases for research.

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