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Short Paper

LMML: Initial Developments of an Integrated Environment for Forensic Data Visualization

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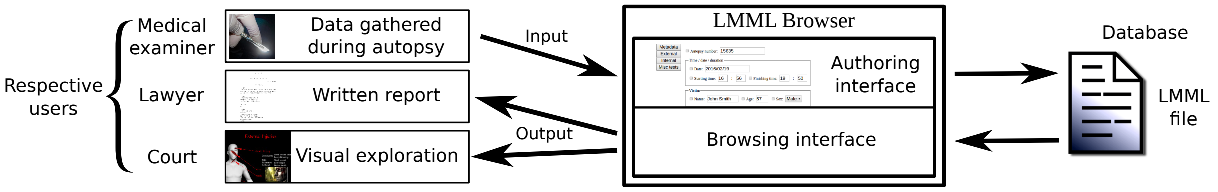

Figure 1: *LMML: Legal Medicine Mark-up Language. General workflow of our framework, with involved users.*

Abstract

Fighting against crime is paramount to any society, maybe more today than ever before. Tools to fight and elucidate crime are rooted in forensic science. Through the autopsy of a body, we can answer a whole range of questions as to how death happened and come up with explanations and counter-measures so that the same dire circumstance does not happen again. Now, because the reports collecting the data are written manually, the recording of the data collected through traditional autopsy still is a cumbersome, time-consuming task. Our framework, based on a mark-up language (that we dubbed "LMML") to store, describe and arrange forensic data, aims at overcoming those issues. Our contribution is twofold: the design of the syntax and semantics of LMML, and the conception of an interface to create, edit, analyse or query files written in that language. Thus, this framework allows quicker, smoother input of forensic data, for better automation and visualization thereof, so that they can be used by medical examiners, investigators, as well as judicial courts.

Categories and Subject Descriptors (according to ACM CCS): H.4.1 [Information Systems Application]: Office Automation—Workflow management

1. Introduction

Finding out the reasons why an individual died is crucial to improving security or preventing similar accidents from happening again, yet it might be even more important to assuage the loved ones' pain or, if crime there is, to determine penal responsibility. That's when forensic science comes up.

Forensics is the systematical, scientific method of compiling, analysing and profiling data or evidence relevant to the unearthing of past events, in order to understand what succession of happenstances led to the given consequences. Now, the word "computational" can be appended to a lot of disciplines, e.g. computational linguistics or computational biology. In the same vein, a body of knowledge called *computational forensics* can be defined. Computational methods provide tools that enable a medical examiner or investigator to better analyse pieces of evidence, otherwise even these experts would be overwhelmed by the sheer amount of information modern data gathering schemes provide [FS08].

In this paper, we propose a framework for computational forensics that allows quicker and smoother input of forensic data collected during autopsy (i.e. the medical examination of a body to uncover the reasons that led to death) through a graphical user interface specially designed to be used while autopsying. From there, the framework can output a graphical visualization of the input data, so that the application be usable and understandable by medical examiners, investigators and judicial courts alike, each with their own points of view. Hence, the proposed integrated environment serves the specific needs of all the stakeholders involved in the handling of a forensic case, as shown in Figure 1.

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2. Related Works

2.1. Non-invasive autopsy

Late research in computational forensics is geared towards characterizing individuality [SS08]. Everyone has heard of DNA or fingerprint analysis. Some research uses visualization techniques attempting to reconstruct crime scenes [BGB13]. The latest trends lie in the use of CT/MRI scans to examine every part of a body. This is what we call *non-invasive autopsy*. *Virtopsy* was the first method proposed to do "virtual autopsy" [TYS*03]. Since then, the method has been refined and is being more and more used in many jurisdictions [BTR*08, LWP*06]. Non-invasive autopsy has the merits of not destroying the body—invasive autopsy being an intrinsically destructive process which, by destroying clues, can hinder the investigators' progress if the inspection were to be botched or not properly recorded. Besides, some people, for various ethical reasons, can also be opposed to invasive inspection [BGB13].

However, as alluring as non-invasive autopsy can be, it still does not suffice to perform a complete examination. Non-invasive autopsy completes, yet does not supersede, traditional autopsy [SSFKJ*09, Und12, WMRW15]. Our research aims at developing tools to improve conventional autopsy workflow, to allow quicker examination and ensuing analysis, contrary to latest trends in computational forensics which, were they to focus on autopsy, fixate only on non-invasive autopsy or the likes.

2.2. Visualization geared towards forensics

Visualization technologies and computer graphics are being more and more utilized in many jurisdictions of late. They are especially used to show injuries or body positions to better understand or demonstrate the succession of events that led to such traumas [Per10]. Though they show convincing results, these are ad hoc methods that require someone competent in computer graphics, because of the heavy manual post-processing that is needed. They call for cooperation between medical staff and computer engineers [UBS*12, BGB13].

Therefore, we want to automatize that cooperation by providing the missing link: a piece of software translating raw autopsy data as input by the medical examiner to computer graphics, which can then be appreciated by untrained personnel, including investigators, prosecutors, lawyers and members of the jury. To that end, we have to create a data model to store, describe and arrange forensic data, thus creating an *ontology* for computational forensics. Ontology is what "defines a set of representational primitives with which to model a domain of knowledge or discourse" [Gru09]. Moreover, the proposed system includes an interface to input forensic data as the autopsy is being conducted. This is crucial in that, some areas, e.g. Japan, are lacking competent medical examiners, leading medical staff to be overly solicited [OSSK13]. Examination must be performed quicker to increase efficiency. In short, our research path is twofold: the design of a semantic language that describes forensic issues (section 3) and the conception of an interface to create, edit, analyse or query files written in that language (section 4).

3. LMML: Legal Medicine Mark-up Language

Consequently, we have been developing a mark-up language to give structure to forensic data. We call that language "LMML", for "Legal Medicine Mark-up Language". This language is based on XML 1.0 specifications (eXtensible Markup Language) defined by the World Wide Web Consortium (W3C) [BPSM*08]. We rigorously defined the semantics of the LMML language using XML Schema 1.1 (XSD files, i.e. XML Schema Definition) [GSMT*12].

We chose to use XML because it is a ubiquitous, portable language, supported on any modern platform and completely queryable. To define the data model, we used samples of forensic reports authored according to the operative procedure certified by the *Japanese Society of Legal Medicine* [Jap16]. The format used by this society is the most widely used method throughout Japan, followed by the majority of Japanese medical examiners for the enforcement of justice. Nonetheless, how standard it may be, the reports are still very difficult to read for non-experts (e.g. jury members in court) because of all the jargon used throughout it, and the lack of visual support. As a result, the use of this report for trials can be a challenge, even though it is a norm imposed by law. In any case, Japanese law will always require the traditional written report, hence our system must be able to generate that report from the forensic data stored inside the database. Thanks to digitalisation, new perspectives to view and analyse such a report are opened. Hopefully, the report structure being quite systematic, it is possible to achieve that objective, and our system can already output almost exhaustive forensic reports.

3.1. Structure and construction

The standard autopsy report samples that we used can be broken down into five parts:

Metadata: Used to store information relevant to the current case: name of prosecutor in charge, appointed examiner, victim's information, etc.;

Conclusion: Brief conclusion of the autopsy;

Explanation: Forensic examiner's interpretation regarding the cause of death;

Examination: The longest and most systematic part, it details all the process of the autopsy, from beginning to end;

Photographs: General photographs of the body are appended to the end of the report.

As one could see, the *metadata* and *autopsy* parts are the most systematic ones, and the easiest to fully digitalize and generate. Fully describing the LMML specifications would be beyond the scope of this paper, due to the length of the schema definition, which contains around 600 nodes. In a word, an autopsy corresponds to one root element named `autopsy`, and everything related to that specific examination goes inside it.

Now, the most difficult part of our system lies in the structure of injuries. Indeed, injuries are diverse and there is no limit to imagination when it comes to humans inflicting harm upon others. We will explain how injuries are encoded in the following section.

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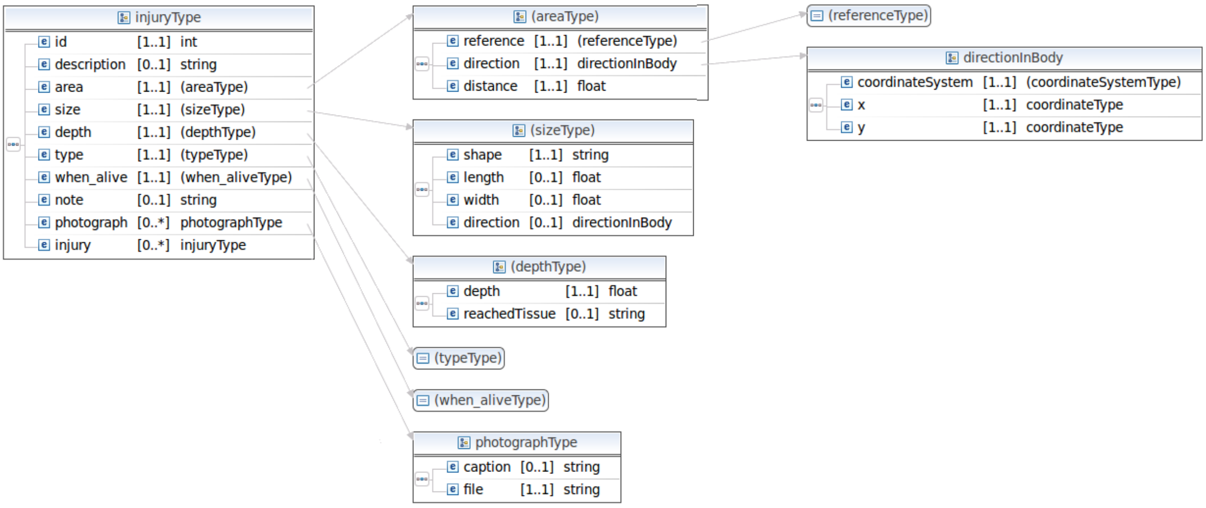

Figure 2: *Data structure for injuries used in the LMML language (detailed excerpt from full schema definition).*

3.2. Type of injuries

We must first explain some details about injuries, as it is the crux of the problem. We must classify injuries so that at least, say, 95% of injuries can be faithfully recorded into the LMML language without need to have the forensic examiner write explanatory text notes. Roughly, forensic experts usually count at least four broad types of injuries [Kni97]:

Abrasions, often called "scratches";
Bruises, which are due to blunt damage to the tissues;
Lacerations, more commonly called "gashes or tears", not to be confused with incised wounds, they are the result of blunt, tearing wounds onto the skin;
Incised wounds, and among them two subdivisions: *slash* and *stab* wounds.

Apart from these broad types, more specific types should be taken into account, like wounds caused by particular weapons, such as gunshot wounds [DiM99, DD01]. The data structure used to show injury can be found as a tree diagram in Figure 2, where it can be seen that a wound is characterized by the following parameters:

Description: A short string qualitatively describing the injury (input not compulsory);
Area: This parameter indicates the exact position of the wound on the body, based on the method described by Burykh [Bur04]. To locate a wound, we store its coordinates in the polar coordinate system whose origin is a fixed anatomical reference point (beware that the coordinate system used depends on the body part);
Size: A parameter containing the shape of the wound, its dimensions and direction (i.e. orientation of the wound along its length);
Depth: Depth of the wound at the deepest point as well as the name of the deepest reached tissue;
Type: Injury type as described above;
When alive: Describe whether the wound was sustained pre-mortem or post-mortem;
Notes: Anything worthy to be noted down that does not fit above;
Photographs: Photographs of the injury, the examiner shall take as many photographs as he deems necessary;
Injury: There can be case of injury within an injury. In that case, an injury can recursively contain another injury.

Thanks to this parametrisation, we are able to recreate the wound on a 3D body model, thus digitalizing all injury information. Nevertheless, some work still needs to be done to locate the reference points at the proper place regardless of the victim's anatomy, especially for individuals with peculiar builds. We will now present the user interface we have developed to manage LMML data.

4. LMML Browser: Input and Output

The interface to handle LMML files is naturally called "LMML Browser", which is written with the Java programming language using the Spring Framework [Piv16]. Thus it runs on a server and is available to any user connected to the same network through a simple web browser, including mobile devices. Several levels of access exist: the medical examiner creates and edits LMML files to record the data while members of the jury would sift the output report and visualization, allowing them to make a better informed judgement. Another strength of this system lies in the increased efficiency provided by the automatic generation of the forensic report for the medical examiners. Moreover, the ubiquity of web technologies makes this application usable in virtually any environment with a device connected to a network, including a police station or a judicial court.

4.1. Input interface

The interface used to input forensic data can be seen in Figure 3. Basically, the interface looks this way for each body part (but there is a quite large amount of them). The interface is split into three regions: general data for the selected body part, injury description, and a preview of the output report for the selected part. Hence, the

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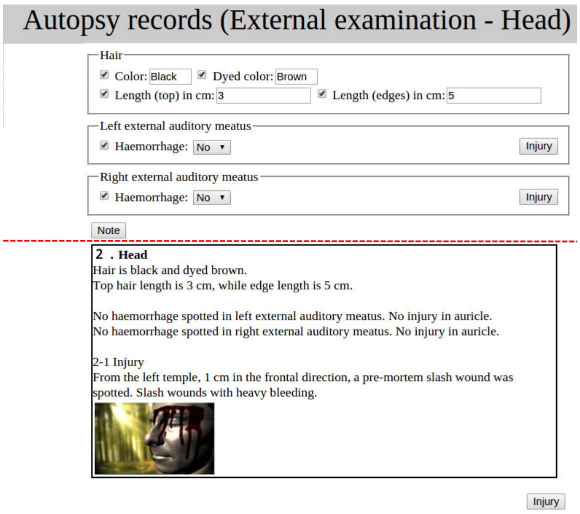

Figure 3: *LMML Browser: Data input interface (head external examination). Top: Fixed forms for data relevant to head examination. Bottom: Preview of the paragraph dealing with the head included in the final forensic report.*

examiners will first input data relevant to the current part (e.g., for the external examination of the head, hair colour or ear bleeding) in pre-arranged forms. Then they can precise the details of the injuries in the injury form, following the data format for injury explained in section 3.2. Finally they can check as they type how the forensic report will be rendered by the LMML Browser according to the current input data by taking a look at the lower portion of the screen.

This input interface also handles metadata for the current forensic case, internal examination and a wide range of common forensic tests (including for example blood, biochemical, histopathological or diatom tests).

4.2. Output: Using the recorded data

As it stands, the LMML Browser gives two kinds of output: the forensic report that would have otherwise been entirely typed like a manuscript and some visualizations of the input forensic data to explore the injuries the victim suffered in a visual and interactive way (see Figure 4). The generated forensic report is very similar to the standard manuscript that has been used until now, and is downloadable in the OpenDocument Format (ODF) or as a PDF file. With minimal polishing, it should be usable as is by courts.

Now, one of the main contributions of this paper lies in the graphical outline allowing to explore the content of the autopsy. To be easily browsable by anyone, we used web technologies: this visualization is implemented in WebGL, OpenGL for the web browser [JG16]. The user can freely move the camera around the body, represented by a 3D virtual mannequin. Arrows are pointing to injuries, with red arrows for external, and yellow arrows for internal traumas. Textures showing the shape of the injury are mapped onto the mannequin's skin, thanks to the coordinate information

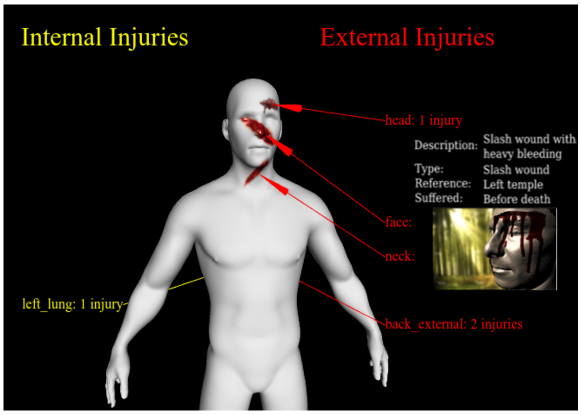

Figure 4: *LMML Browser: A visualization to explore the result of the autopsy.*

the physician previously input. By clicking on a body part, pop-up windows appear showing all the detailed information about injuries for the selected part, including photographic references.

5. Conclusion and Future Work

This paper is an initial report on a novel computational forensics framework to allow investigators or members of courts to explore autopsy data. The framework, while being promising, is still lacking refining. This framework must be put to test in real-life cases and in courts. Besides, quality of visualization must be improved to have a sliceable/segmentable mannequin with the same silhouette as the victim. As is, it is very difficult to visualize an internal injury unless there is texture for it. Relating external to internal injuries and vice versa is essential as well.

In addition to the issues raised above, a framework dealing with forensic data has everything to gain from implementing data provenance management, e.g. an implementation similar to VisTrails from Silva [SASF11]. Moreover, some works geared towards directable visual simulation could be a source of inspiration for that project. For example, blood flow simulation as implemented by Ueda [UF15] could be used to create more realistic textures from the input information about the wound, while non-photorealistic image filters could mitigate the level of gore to alleviate potential effects on jury members' mental health.

We believe that, as the world gets more and more digitalized, law enforcement should also get to ride the same tide (as it has begun), be it by ours or other researchers' projects. One could say that the advent of computational forensics is on par with the late developments of computational journalism [And13].

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