A methodology to event reconstruction from trace images

Quentin Milliet *, Olivier Delémont, Eric Sapin, Pierre Margot

Institut de Police Scientifique, Ecole des Sciences Criminelles, University of Lausanne, Batochime, CH-1015 Lausanne, Switzerland

A B S T R A C T

The widespread use of digital imaging devices for surveillance (CCTV) and entertainment (e.g., mobile phones, compact cameras) has increased the number of images recorded and opportunities to consider the images as traces or documentation of criminal activity. The forensic science literature focuses almost exclusively on technical issues and evidence assessment [1]. Earlier steps in the investigation phase have been neglected and must be considered. This article is the first comprehensive description of a methodology to event reconstruction using images. This formal methodology was conceptualised from practical experiences and applied to different contexts and case studies to test and refine it. Based on this practical analysis, we propose a systematic approach that includes a preliminary analysis followed by four main steps. These steps form a sequence for which the results from each step rely on the previous step. However, the methodology is not linear, but it is a cyclic, iterative progression for obtaining knowledge about an event. The preliminary analysis is a pre-evaluation phase, wherein potential relevance of images is assessed. In the first step, images are detected and collected as pertinent trace material; the second step involves organising and assessing their quality and informative potential. The third step includes reconstruction using clues about space, time and actions. Finally, in the fourth step, the images are evaluated and selected as evidence. These steps are described and illustrated using practical examples. The paper outlines how images elicit information about persons, objects, space, time and actions throughout the investigation process to reconstruct an event step by step. We emphasise the hypothetico-deductive reasoning framework, which demonstrates the contribution of images to generating, refining or eliminating propositions or hypotheses. This methodology provides a sound basis for extending image use as evidence and, more generally, as clues in investigation and crime reconstruction processes.

1. Introduction

The aim of this paper is to propose and describe a methodology for exploiting the investigative potential of images to reconstruct past events. Events and crimes are often recorded by surveillance cameras and are observed and recorded by witnesses or bystanders. Recorded images become recorded traces, which are a valuable source of clues to understanding what happened. Images provide information about persons, objects, space, time or actions. The contribution of images as vectors of information, while recognised by investigators, is most often ignored in the forensic science community, whose primary focus is on identification and evidential value of images [1]. During the investigative phase of an inquiry, forensic science is a crucial provider of information; it helps suggest and assess propositions, clarify sequences of events and prioritise lines of enquiry. By analogy, recorded images provide many clues and have great investigative potential. However, using images for such purposes has not been well-explored, formalised or described. A structured approach is required for integrating images as

traces or remnants of the past in the reconstruction process for specific events. We propose a methodology to using images in the framework of an investigation. Our solution anchors the wide emerging field of image analysis to fundamental forensic science concepts by explaining how trace images are transformed progressively into meaningful information.

1.1. Research strategy

The methodological aspects of image analysis have been studied in other disciplines, such as sociology [2]. Tools such as semiotic, composition and content analysis have provided a useful core basis for constructing the methodology, which required consideration of issues concerning the use of images as traces that are relevant to the forensic science perspective. Recurrent observations from case studies led to the development of a core methodology.

After the first conceptualisation phase, the methodology was tested and further refined through application to other cases; these practical cases involved an analysis of witness images (videos or photographs) with an ambiguous or incomplete meaning. We do not consider image manipulation or falsification part of the methodology. The aim of this

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strategy is to extend the validity of the formalised methodology to the following contexts and cases:

1. The Truth for Reconciliation Commission of Thailand (TRCT) is a truth-seeking initiative that focused on "*the violent events that took place in Thailand, especially during April and May, 2010*" [1] and led to 92 deaths with over 1500 injured [3,4].[2] The methodology was applied to reconstruct two specific events in this particular context; one of them is used as an example in the section Case study 1.
2. In the context of the Swiss criminal justice system, the methodology was applied to two homicide cases. These are described in the section Case study 2.

Below, we propose an overview of the methodology, followed by a detailed analysis of each step, examples from the case studies and a discussion addressing the perspectives and limitations.

2. Methodology

The methodology provides guidelines and articulates concepts at a higher level of generality than in applying techniques; it is a sound basis for guiding the use of particular tools. The methodology was constructed in a sequential manner and consists of four main steps that are intimately related; each step relies on the results from the previous step. However, the methodology is not linear, but it is a cyclic and iterative progression of constructing information. Input, such as new material, reference data or other sources of information (e.g., reports, statements, and intelligence) are integrated into the process.
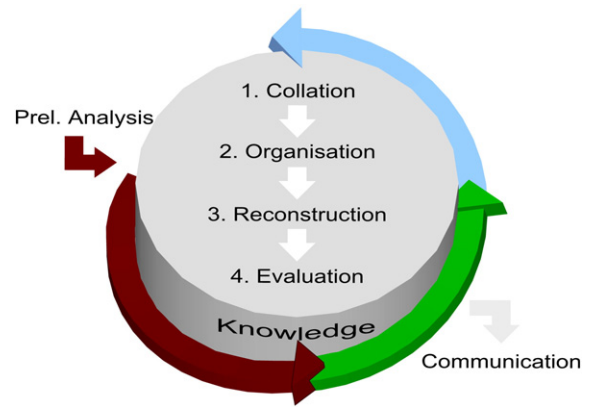
The methodology begins with a *preliminary analysis* (Fig. 1). The case and its circumstances, the questions asked and material submitted are considered to address the relevance, reliability and feasibility of the analysis as well as define specific objectives. This approach highlights expectations given reasonable propositions [5].

The first step, *collation*, concerns image detection and collection as pertinent traces as well as their order. The second step describes their *organisation* with an emphasis on trace classification, review and selection. The third step, *reconstruction*, focuses on the information extraction and combination. The fourth step, *evaluation*, describes the selective production of information and opinions that indicate their strength. *Communication* through memos, structured reports or demonstrations is output from the process; the various forms of communication are directed at different audiences and produced at different analysis stages.

Each step explicitly describes what happens during image analysis and processing (from photographs or videos). We emphasise the hypothetico-deductive reasoning framework, which aids the reconstruction process using images as clues. Abduction generates propositions about plausible causes for the clues, and deduction is used to examine these propositions with other clues, which may corroborate, refine or eliminate the propositions. Reconstructing an event from traces is similar to the clinical reasoning process used to form a diagnosis based on symptoms [6].

2.1. Preliminary analysis

Before beginning the technical work required for the image analyses, background information must be collected and digested to understand the context and particular situations in terms of locations, protagonists and approximate chronology. Despite the risk of bias, determining the context is essential; given the large scope of action and the extent of available images, background information aids in delimiting relevant questions and, thus, identifying the required resources.

[1] Regulation of the Office of the Prime Minister on the Truth for National Reconciliation B.E. 2553 (2010).
[2] http://issuu.com/thai_e-news/docs/final_report_trct_17_9_12.

Fig. 1. Schematic description of the methodology with the preliminary analysis (initial input), the four main successive and iterative steps and the communication (output). New material or information may be integrated into the cycle at different steps; the findings may also be immediately communicated; the arrows represent the cyclic progression of knowledge.

Available information on the case under scrutiny provides an overview of the circumstances, pending questions and existing documentation (crime scene, investigation or autopsy reports, maps, sketches, notes, witness statements and forensic science reports that analyse material traces, such as gunshot residues, explosives, DNA, and fingerprints). Investigators or magistrates may provide such information. A briefing or visit to the scene may be necessary for familiarity with the locations and their configuration.

Knowing the context aids in determining the propositions that must be examined with unknown areas that must be explored; this is the basis of the approach. Unknown elements guide the analysis. As information increases, the questions evolve from general to specific. Specific questions aid in defining clear and achievable objectives that correspond to portions of the answer. Attention should be given not to answer questions directly using images because it may lead to the transposed conditional fallacy [7]. In a Bayesian framework, this error refers to transform a statement about the probability of an observation given a proposition about the activity under scrutiny directly into a statement about the probability of the proposition. Attention should be given that wrongly framed questions may lead to wrongly framed statements or answers, as many explicit examples can be found in the literature [8].

Priority objectives should be defined with each stakeholder to reach an agreement between their expectations and realistic outcomes from the forensic science analysis. Accepted objectives direct the process, and new relevant element may be added.

2.1.1. Material

Material may or may not be collected before the analysis begins. If it is collected, a global but critical review of the material submitted facilitates an assessment of whether the agreed-upon objectives can be fulfilled. The analysis is only feasible if the images may be informative. Otherwise, either more material must be collected, or the analysis cannot be performed. When no material has been collected, the context and questions should guide collection of relevant images.

The material authenticity and integrity is considered when assessing the possibilities. Image manipulations may be discerned, and the original material should be collected if possible.

2.2. Step 1. Collation

2.2.1. Detection

A preliminary analysis of the event leads the search for images related to the case under scrutiny. This approach is analogous to a search for traces in a crime scene and its extensions. Indeed, detection is not