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Forensic intelligence and crime analysis

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Computerized databases have been developed in forensic science to provide intelligence for the investigator. For example, automated fingerprint identification systems (AFIS) and DNA databases efficiently help identify potential suspects or, particularly for DNA, link crime scenes. Other evidence such as various marks transferred during the offence, items left by the offender (such as clothing or accessories) or information captured through devices such as surveillance cameras could also be exploited systematically to provide similar intelligence. However, if such systems exist under the form of operational databases, they commonly struggle to overcome computational complexities pertaining to the retrieval and comparison of traces from large quantities of data. Thus, the use of forensic case data combined with the temporal and geographical dimensions of the crime is often felt as a necessary development, but the circumstances in which the visualization of traces on maps can help to provide accurate and useful analyses remain to be identified.

A limited study will illustrate the potential of forensic case data to provide intelligence through inferences which vary from the traditional model initiated by DNA and AFIS databases. Specifically, it shows that the occurrence of certain characteristics of shoemarks, toolmarks and/or glovemarks can be concentrated in geographical areas and/or during delineated periods of time. These clusters can then be scrutinized to help reveal a series of potentially linked crimes. The experiment confirms that this two-step process, which does not require the implementation of complex computer systems, can be systematically applied as a crime analysis method and as an investigative tool.

Keywords: intelligence-led policing; crime analysis; forensic intelligence; shoemark; toolmark; glovemark.

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1. Introduction

The evolution of policing strategies and new technologies has dramatically increased the role of intelligence in law enforcement agencies. Despite difficulties implementing former community-based and problem-oriented (Goldstein, 1990) philosophies beyond specific experiments (Brodeur, 1997), it is now generally recognized that intelligence has an important role to play in both the diagnosis of insecurity problems and the design of targeted, preventative actions (Gottlieb, 1998). The strategic allocation of resources to the most significant problems and the measure of police performances (essentially through crime reduction indicators) provide additional managerial motivation for enhanced intelligence-based approaches to policing.

The increased role of intelligence has been augmented through the creation of crime analysis units within police organizations. However, the implementation of these new structures has occasionally encountered resistance. It is not always clear why the police should expand their role when there is often a lack of resources to carry out their traditional job. Ideologically, the new strategies can be perceived as reducing the importance of single investigations and consequently changing the role of the investigator. Moreover, it opens the door of the confined police community to civilian employees. Finally, crime analysis is a transversal process across vertical hierarchies; these favour the obedience to traditional hierarchical demands whereas demands by other colleagues or services may be answered but in a low priority order. These may be compounded by traditional boundaries jealously preserved as specialist fields of expertise.

As a result of this background, crime analysis has attracted researchers from different academic communities such as geography, psychology and criminology. Their work has provided the domain with an impressive set of models, methods and computerized tools (Gottlieb, 1998; McGuire, 2000; Peterson, 2000). Moreover, thoughts about the relationships between criminal intelligence analysis and specific bodies of scientific knowledge are now appearing in the literature, for example in the discipline of psychological profiling (Atkin, 2002).

Forensic scientists have also participated in the debate, mainly through the development of databases (Sprangers, 1997), but also through crime reduction projects and research programmes that encourage increased utilization and awareness of forensic science among all the contributors of the criminal justice system (FSS, 2000; NIFS, 2002)

This change of attitude has led to more funding, a remarkable technological expansion and specific successes in crime solving. For instance, innovative uses of databases provide new forms of intelligence that were previously unimaginable or simply precluded by legal rules (Anonymous, 2002). However, whereas recent progress allows forensic intelligence to assist better the police in specific criminal cases, there is still a lack of understanding of how to go beyond traditional identification, such as is possible through DNA or AFIS databases (Walsh *et al.*, 2002).

Other forensic science research suggests the systematic use of traces like shoemarks, combined with geographical information in order to provide crime scene linking (Birkett, 1989; Milne, 2001; Napier, 2002). These approaches help to narrow the gap between forensic science and crime analysis but fail to make this intention explicit. Intelligence-led policing tempts forensic science to operate in a new context, within which it is yet to find its place (Walsh *et al.*, 2002).

Previously (Ribaux & Margot, 1999, submitted) we have proposed a framework for crime analysis that fully integrates forensic case data. It was argued then that this conceptual model should be based on two main components:

- a structured memory that represents the knowledge we have at a certain time about the criminality under consideration: current problems, active series, cases linked, etc. (basic intelligence).
- an organized repertoire of systematically, frequently or possibly applied inference structures that reveal how to combine the use of different types of data in the course of the analysis.

This framework helps understanding of the relationships between forensic science and crime analysis, the design of specific intelligence processes and computerized systems, the interpretation of new situations in the light of what is already known, and the integration and organization of the knowledge originating from these new experiences. It also provides an opportunity for initiating the debate about management of memory and treatment of uncertainty.

The concept of intelligence will be recalled and extrapolated to the forensic context. A review of traditional inference structures that are applied through the use of forensic databases will follow. Finally, we illustrate how innovative inference structures can enrich our existing collection. The examples provided have been successfully applied in actual cases and have a great potential for systematic exploitation as a crime analysis method.

2. Intelligence

It is generally recognized that intelligence is the timely, accurate and usable product of logically processed information. In the context of the criminal justice system the information pertains to crime and the context in which it occurs. For instance, from a series of crimes, a hypothesis about where the criminal lives or when and where he will next offend can sometimes be inferred from the available data. These judgements provide leads that are then translated to operative measures like surveillance or targeted police patrols.

This interpretation step, called analysis, is often considered as the heart of a process embodying the whole treatment of data, from its collection to the practical implementation of the intelligence itself (‘the intelligence process’, see Peterson, 2000).

Analysis can involve a variety of knowledge from different specialized fields such as criminology, computer science, psychology, forensic science and economics. Reasoning on imperfect information (which is systematically uncertain, incomplete, imprecise or even contradictory) can generate intensive debate, in those domains where inferences are carefully studied and discussed, with the aim of providing intelligence through well grounded criminal investigation methods. However, a lot of effort is generally dedicated to the construction of elaborate formalisms whereas the accuracy of the results in the real context of the investigation can vary broadly. The practical benefit of these research activities is sometimes difficult to evaluate and even questionable, as for some psychological approaches (Beauregard & Proulx, 2001; Santtila *et al.*, 2003).

Contributions from specialized domains are often considered a complement to crime investigation by implicitly making the assumption that the intelligence will be integrated

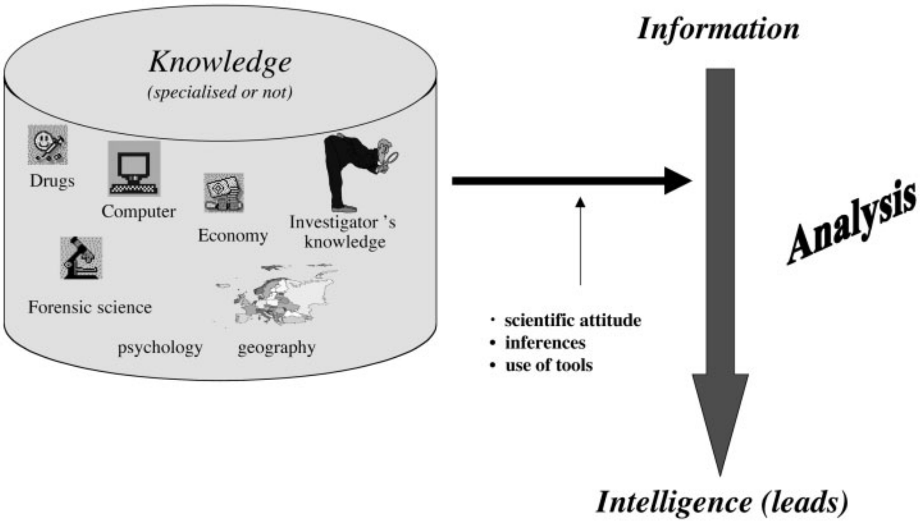

FIG. 1. From information to intelligence.

via well defined investigative frameworks. In actual fact, criminal investigation is rarely formalized and mostly requires the processing of common sense knowledge (Kind, 1987; Ribaux *et al.*, 2002). Criminal intelligence analysis should therefore be considered as a domain that provides methods and techniques that assist the integration of data and various bodies of specialized knowledge, the result of which is to structure better the reasoning processes used in the course of investigations and to communicate effectively the results to partners (Fig. 1).

3. Forensic intelligence

By definition, forensic science already plays an intermediary role between specialized fields of science and law enforcement. Repeating our earlier definition, forensic intelligence is the accurate, timely and useful product of logically processing forensic case data. It can be illustrated by Fig. 2. Of importance is the implication of an additional level of consideration, where collectively (across numerous investigations or various disciplines), the outcomes of forensic analyses become the source of intelligence.

3.1 *Inferences and their context*

It is generally recognized that the practice of forensic science is founded on four basic inferences, or processes: identification, individualization, association and reconstruction. They aim to help, in various degrees, answer investigative questions of 'who? what? where? why? when? and how?' (Inman & Rudin, 2001)

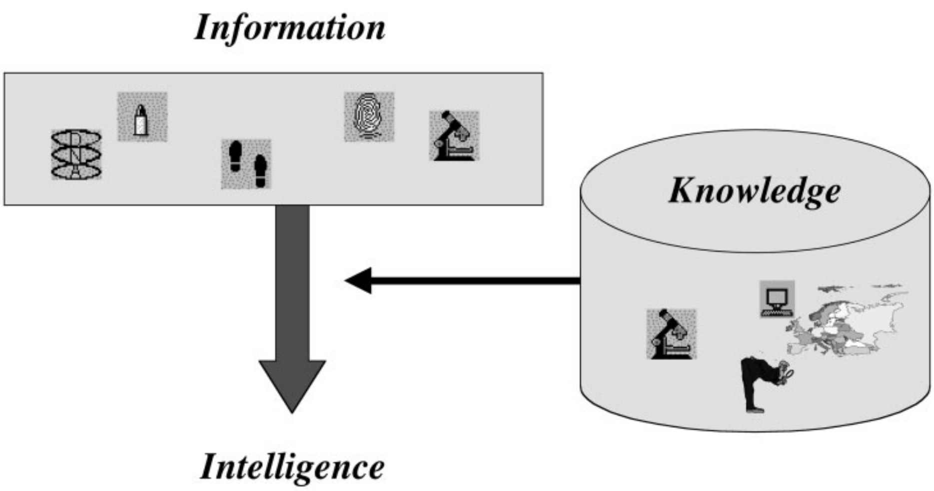

FIG. 2. Forensic intelligence.

The paradigm suggested by Kind (1994) captures the different contexts in which those inferences are carried out. He considers the crime investigation process and its subsequent criminal trial, within a framework composed of three ‘chapters’: the problem to find, the decision to charge and the problem to prove. A globally inductive reasoning process leads to the identification, localization and arrest of authors of crimes (first chapter), whereas logical inferences become essentially deductive when the investigator has to refine and check his standpoint and remains convinced he has the right culprit in his hands (second chapter). The trial itself constitutes the third chapter. Forensic science traditionally focuses on the second and third chapter, whereas criminal intelligence and consequently forensic intelligence are mainly concerned with the first chapter, even if the knowledge gained a priori can be re-used and refined after the arrest of a suspect.

4. Databases and inference structures

The use of AFIS and DNA databases illustrates one of the most common forms of analysis that is based on forensic case data: helping to determine the source of a trace. Recent and innovative approaches allow the extraction from the databases of frames delineating more than one individual. For example, the comparison of a partial DNA profile, select features from a mixed DNA profile, or a putative DNA profile (which has for example been constructed from the profile of family members) may match many samples contained on the database (see Fig. 3).

Such results, however, are still frequently misunderstood by investigators who have a tendency to view DNA and fingerprint findings as a definite determination of the source of a trace. This confusion emphasizes the importance of the definition of the context in which those databases are used, in criminal intelligence (chapter 1) or as the demonstration (proof,

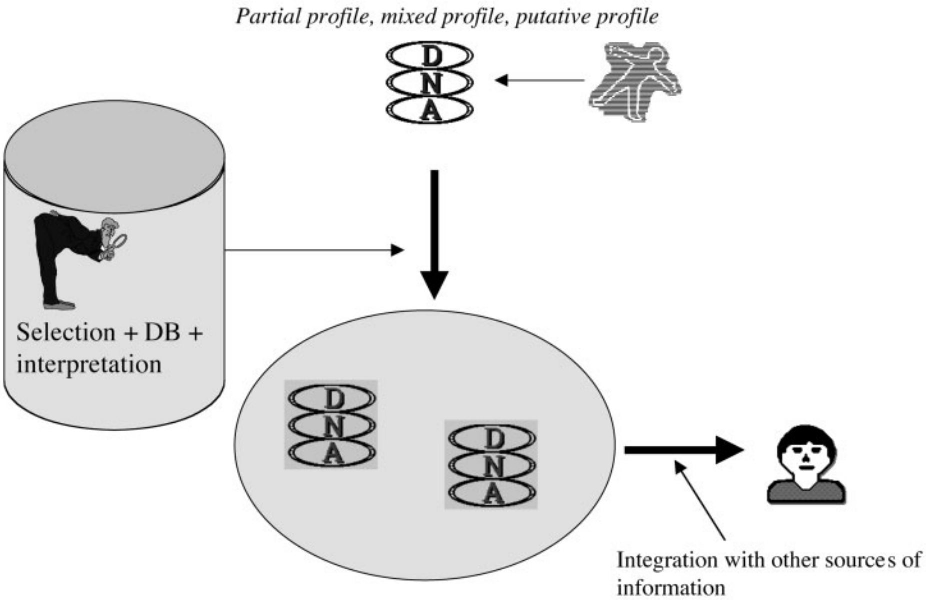

FIG. 3. Using DNA databases to identify possible suspects through the comparison of incomplete DNA profiles. Subsequent combination with other forms of intelligence can then assist with the identification or investigation.

chapter 3), in order to avoid misunderstanding and loss of intelligence because the scientist will not take the risk to have their results used for any purpose other than the 'final proof'.

4.1 *Identification of the source: limits of other databases*

Despite these potential ambiguities pertaining to an extension to the role of the databases, DNA and AFIS systems are very efficient as an aid to the identification of an offender. However, an expansion of the platforms upon which they are based to include other types of evidence is not straightforward. Matching and retrieval algorithms used to identify and compare traces in large quantities such as DNA and fingerprints are successful, but the transposition of these algorithms to other databases encounters difficulties in overcoming the different levels of complexity associated with the fragmentary and visual nature of trace evidence types. This has been demonstrated through experimental attempts at utilizing toolmarks or shoemarks in this fashion. Moreover, when the source of a trace is an object or an accessory that a criminal can discard, the chance of obtaining links with stored data decreases and the accuracy of the database is reduced. These drawbacks do not mean that marks of objects and accessories collected are not worthy of treatment through computerized systems. They should rather be considered as a support not only to identify the source, but also along other reasoning patterns that combine different sources of data (Ribaux & Margot, 1999). Comparison of shoemark databases used in forensic laboratories illustrates the lack of understanding of this expanding role of physical traces in criminal intelligence: their structure, size and intentions vary broadly across jurisdictions (Majamaa, 2000). The disparity of contexts within which these diverse databases operate illustrate the difficulty because they have not been developed within a conceptualized framework.

Thus there is a need to study the circumstances in which various types of physical traces can provide intelligence through treatment of the data collected. The role of DNA databases, for example, can be expanded beyond their traditional use in identifying the source of a biological trace.

4.2 *Expansion of the role of DNA databases*

When DNA databases were developed, the whole process, from the collection of samples to the interpretation of results, was carefully designed towards the goal of identifying the source of an individual trace, even if there remained some room for variation (see above). What was certainly known but generally very poorly anticipated when implementing the database process is that DNA has a great potential for scene linking. The forensic community is itself often sceptical about the importance of this ‘side effect’, highlighting once again poor understanding of the potential of trace evidence for intelligence purposes, although its validity, reliability and inherent indicative power is often much stronger than any other investigative type of information (witnesses, observation, etc.). Every forensic practitioner has heard in his or her professional circle that ‘it is of no use to connect cases because it does not give the name of the perpetrator’. At least in Switzerland, but certainly also in other countries, no systematic management of this information has been planned. This passivity is largely influenced by the traditional role of forensic science within the criminal justice system, but is ignorant of the fact that linkage is a basic inference in criminal investigation and in crime analysis. This information should be stored, treated and exploited in combination with other types of data.

A case example helps to illustrate this point. Over a three year period, a burglary problem was revealed and when studied by the regional crime analysis unit it was found to extend over the entire region across multiple political boundaries. A link was provided by the DNA database that showed the existence of a series (same perpetrator). It connected two specific cases located at opposite ends of the region of interest. The analysis of the files where individuals had been identified as the sources of traces collected in cases of that nature led to the identification of a suspect, a known burglar residing in a neighbouring country. Subsequent investigations led to his arrest and it has since been verified that his DNA corresponds to the traces collected in the original linked cases. A large number of previously unsolved cases have been subsequently attributed to this individual.

In this example, a new link has been interpreted through a priori knowledge about the current structure of burglary in one region and along a rather complex inference pattern (see Fig. 4).

Usually, this kind of knowledge is disseminated among investigators that treat specific cases. The implementation of a crime analysis unit allows the centralization, integration and interpretation of that information in order to draw a general picture of criminal problems that can in turn help to interpret new and specific situations.

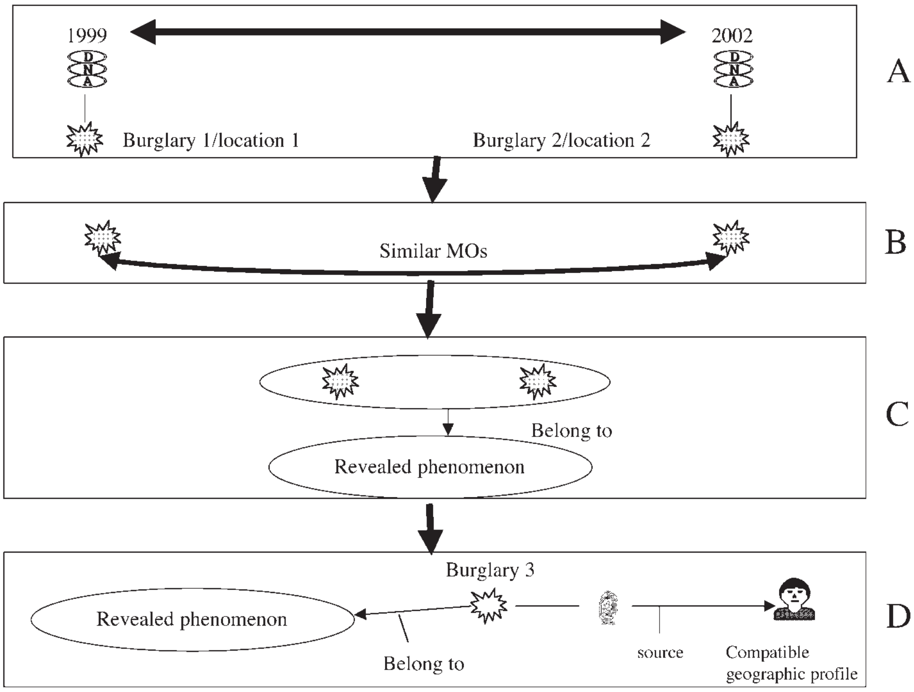

FIG. 4. Two crimes had similar modus operandi (B) were confirmed as part of a series through a scene-to-scene DNA match (A) and subsequently linked to a broader phenomenon (C). Consideration of other knowledge from the broader phenomenon identified a suspect (D) who could be identified through various traces in a multiple offence case.

5. Crime analysis

Crime analysis aims at revealing problems, analysing their potential causes and trying to foresee their development in order to determine where best to target law enforcement resources. A combination of exploratory, statistical and visualization methods help reveal patterns in large quantities of information. The information itself is an integration of a broad variety of data representing for example crime incidents, physical environments, socio-economic and demographic features of a population, or physical traces.

The revelation of crime concentrations (known as 'hot spots') is essential in this context as it focuses attention on delineated problems which define themselves via a tendency for similar incidents to occur in the same vicinity. These concentrations are generally geographic, but they can also be temporal, such as the increased incidence of crime during a certain period of time. Additionally, concentrations can represent the occurrence of a high number of certain types of crimes, the frequent use of a specific *modus operandi* by the offenders, common characteristics among victims of crime (known as repeat victimization), or have a basis in the social, demographic and physical environment within which the crime is perpetrated. The identification of extraordinary concentrations based on the combination of these types of data can indicate the existence of a problem, in particular a crime series. Part of this process can be computerized. Despite physical traces being rarely mentioned among the dimensions, they can contribute to the identification of crime 'hot spots'.

6. Crime 'hot spots' through shoemarks, toolmarks and glovemarks

The identification of a crime series through scene linking is possible through the exploitation of shoemark databases. However it is recognized that there are difficulties in computerising the collection, storage and retrieval of information (Girod, 2002). Particular drawbacks that have been identified include the difficulty in controlling the input of data and defining adequate structures to represent fragmentary traces accurately and allow suitable retrieval. To date, no satisfactory matching algorithms capable of automatically and efficiently proposing links are available. A more suitable process for extracting promising candidates from the database would be to proceed along complex inference structures that combine additional types of data (Birkett, 1989; Milne, 2001; Napier, 2002). Similar considerations have been made for toolmarks (Davis, 1981; Geradts *et al.*, 1999; Ahlhorn *et al.*, 2000). Glove marks are generally not used in this context, although we have found that they are detected in 10–15% of burglary incidents (Mizrahi, 2002). A limited study has been established to propose a crime analysis method that exploits those small amounts of information in an intelligence purpose, and preliminary findings are reviewed below.

6.1 *A limited study*

6.1.1 *Objectives.* An exploratory study was carried out in order to show that 'hot spots' of crimes can be potentially revealed based on traces of a fragmentary nature, without the implementation of complex matching algorithms.

This approach demonstrates the potential for the systematic application of a practical two-step crime analysis method using forensic case data:

(1) Provide promising set of cases from extraordinary concentrations of crime identified based on common general characteristics of shoemarks, toolmarks and/or glovemarks.
(2) Further scrutinize and combine with other types of data in order to find links or allow assumptions about the existence of a crime series.

6.1.2 *Method.* An exploratory approach has been used to reveal concentrations of burglaries where traces with similar characteristics have been collected. No mathematical model has guided the exploratory process or been used to assist the interpretation.

A very general classification system has been defined for each of the three types of traces and implemented through databases of stored evidence collected during 2000 and 2001 for shoemarks and toolmarks, and from 1999 to 2001 for glovemarks. In order to satisfy practical constraints, the level of generality and the nature of the classification system was chosen to limit the time required to input data and the dependence on individuals that carry out this task. The classification system for shoemarks was based on 30 patterns generally collected at scenes and the database contained more than 3000

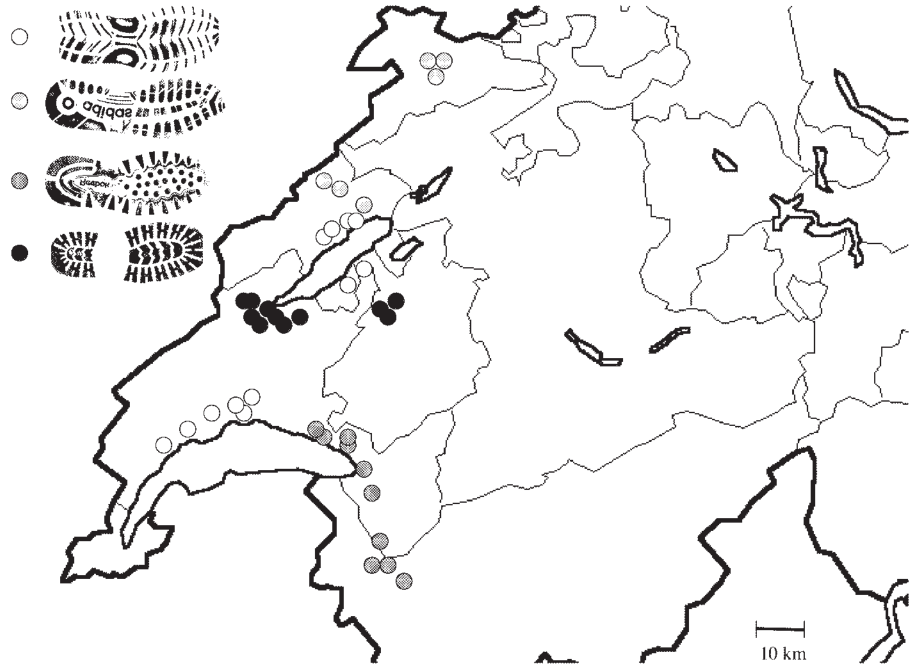

FIG. 5. Hot spots based on shoemarks

traces. The toolmark database was limited to traces made by pliers used by the offender to break the locks of doors and contained 128 records. The width of the trace made by the pliers was stored. Glovemarks were classified in four categories representing the make of the glove and combined in a database containing 441 traces. Images were also stored in order to help scrutinize further specific selections of sets of cases.

The visualization of isolated sets of data was facilitated by the use of a computerized crime mapping system that has been specifically developed to analyse serial burglaries. This also simplified the interface with each of the databases (Ribaux, 1997, 2001; Ribaux & Margot 1999).

The analysis process started by extracting from each database cases that corresponded to each given pattern. The selected cases were then displayed:

- on a map in order to reveal ‘hot spots’
- on a cumulative diagram showing the occurrences of cases over time, with the aim to reveal increases and decreases in the appearance of patterns

6.1.3 *Results.*

Shoemarks. Shoemarks have shown a great potential using our approach. Some examples of interesting groups of cases to be further scrutinized are shown in Figs 5 and 6

Toolmarks. Even with a small amount of cases, patterns have been revealed with only the

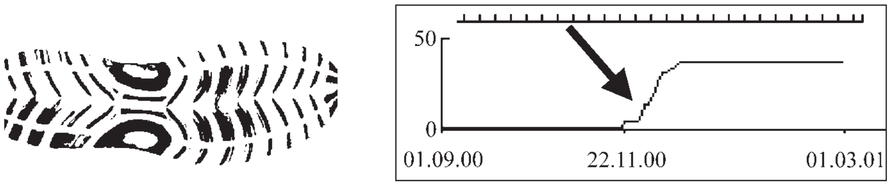

FIG. 6. Concentration of crimes during a certain period of time, where shoemarks with a similar pattern have been collected.

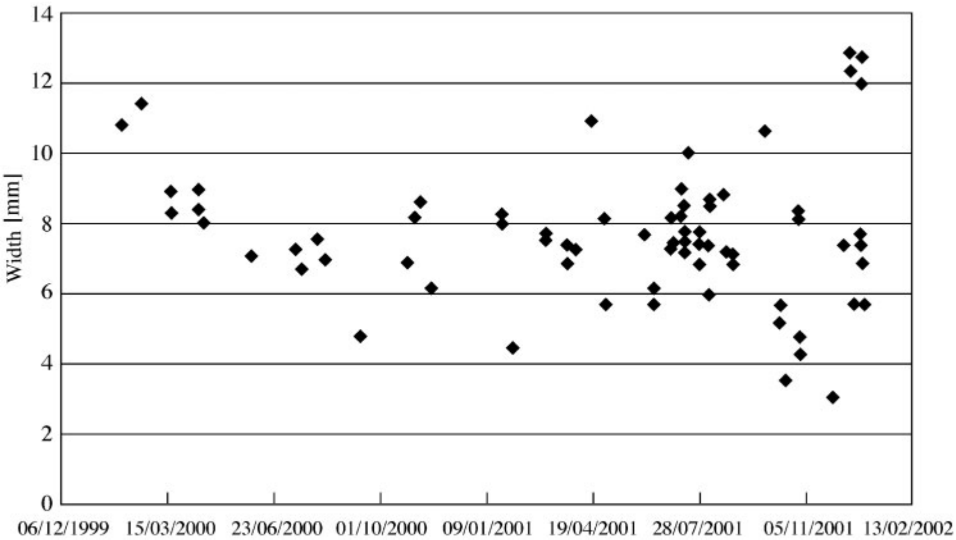

FIG. 7. Appearance of width of toolmarks made by pliers that show concentrations.

width of the toolmarks found at the scene. The burglar can obviously discard his or her pliers after each case. However, it can be assumed that burglars are reluctant to change the type of pliers used and consequently, one can expect that the width of the marks found at the scenes will be similar for the same burglar. Even if it will be difficult to subsequently conclude that the same pliers have been used, concentration of the appearance of similar marks has the potential to reveal the activity of a particular burglar. Figure 7 shows the patterns found following the analysis of the toolmark evidence. It highlights a sort of ‘hot spot’ that should help direct the attention of investigative services

Glovemarks. Similar results have been obtained by analysis of the different categories of glovemarks. An example of interesting tendencies is shown in Fig. 8.

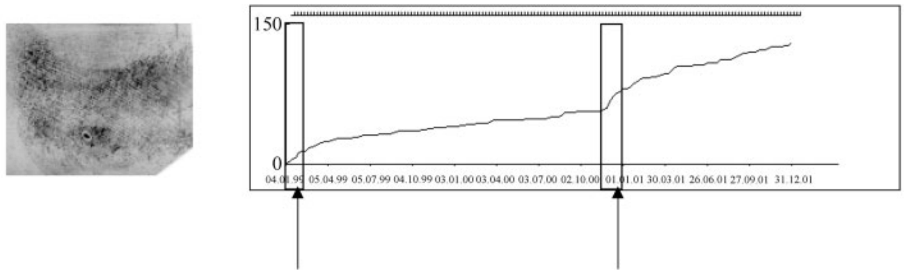

FIG. 8. Concentration of crimes during a certain period of time, where glovemarks transfered by gloves of the same make have been collected.

6.1.4 *Discussion.* The proposed two-step method has shown a significant potential. By exploring the data along the classification dimensions numerous interesting patterns have been revealed. The computerized systems have proven to be very simple to use and were developed without a requirement for highly specific knowledge. Moreover, due to the level of generality inherent in the classification systems, the input of data is fast and largely independent of the individual responsible. From a practical point of view, one can consider that the method is appropriate to be carried out systematically in a routine crime analysis perspective.

Until now, most researchers dealing with the development of databases have focused their attention on the use of expert techniques aimed at finding matches through complex algorithms based on distance computation or neural networked platforms. Our method provides a practical alternative by using small amounts of information along alternative inference patterns. Thus the focus of future research could be to:

(1) computerise the exploratory method fully by developing a computational model which is able to extract tendencies and clusters of traces,
(2) consider the combination of clusters provided by each trace,
(3) expand the approach to other traces, such as earmarks.

Of importance will be the development of exploratory tools that will include the management of visual information.

7. Conclusion

This paper illustrates that forensic case data are still poorly integrated into crime analysis and the investigative process. There is a lack of theoretical framework in which to classify problems and experiences. The study of inference structures abstracting from consideration about computer systems and the adaptation of crime analysis methods in a forensic intelligence context are adequate dimensions to start building such a framework. Our study has shown that with small amounts of information and a few basic computer skills, it is possible to extract interesting patterns and intelligence. This presents an opportunity to change the research agenda by focusing more on innovative methods that combine the use of different traces, rather than concentrating solely on finding ways to develop similar systems as AFIS or DNA databases for other forms of trace evidence.

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