The RISEN Project – A Novel Concept for Real-time on-site Forensic Trace Qualification

Topic: Other C2 Related Research and Analysis

Paper 123

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Abstract

Following a chemical or biological attack, the rate at which a forensic investigation proceeds is critical for capturing perpetrators and preventing future incidents. Crime Scene Investigation (CSI) is a process that aims at recording the scene as it is first encountered and recognizing and collecting all the physical evidence potentially relevant to the solution of the case. Conventional CSI processes involve sensitive and delicate steps related with the identification and transportation of *traces* that may subsequently be subjected to laboratory analysis, a process that can take several hours or days.

In this paper, we present the Real-tIme on-site forenSic tracE qualificatioN (RISEN) project, an innovate concept in forensic investigations in the context of CSI of sites affected by a chemical or biological attack. Coordinated by ENEA, RISEN will develop a set of network-enabled real-time contactless sensors for handling traces on site and accurate 3D recreation mechanisms of the entire crime scene, providing an immersive environment for investigators to evaluate hypotheses and conduct highly detailed investigations. The RISEN concept will allow forensics investigators and judicial authorities, to gather high quality information from a vast list of visible and invisible traces (localisation, identification/classification, interpretation and labelling) from a crime scene through standardised reports and a secure way, also speeding-up the forensic investigation process.

The RISEN project started in July 2020 and has a duration of 4 years.

RISEN public information can be assessed at the project website https://www.risen-h2020.eu/.

Keywords: Forensics Analysis, CBRNe, 3D reconstruction, Horizon 2020.

1 Introduction

Following a chemical or biological attack, the rate at which a forensic investigation proceeds is critical for capturing perpetrators and preventing future incidents. Providing a fast and accurate response in the initial phase of the investigation directly on-site can be crucial, since it will allow directing subsequent law enforcement actions towards well identified individuals or groups, supported by collected evidence and under the rule of the law.

Crime scene investigation (CSI) is a process that aims at recording the scene as it is first encountered and recognizing and collecting all the physical evidence potentially relevant to the solution of the case. Despite its advances and scientifically proven methods, the conventional CSI process still presents a number of issues: when personnel, especially non-forensic staff, interact with the crime scene there is always a risk of the evidence being contaminated, lost or destroyed; relevant *traces*[1] might be altered, missed or, after being collected, the subsequent laboratory analysis process may result in the destruction of the sample; the laboratory analysis process can be lengthy, usually taking several hours or days. Time becomes a scarce resource especially in scenes where preserving traces might be challenging, such as outdoor environments. In addition, the environment might be hazardous for humans in case a dangerous biological or chemical agent is present in the scene.

Novel approaches can be developed to improve the CSI process - making it faster and safer for investigators, without compromising reliability – while assuring a sound scientific methodology. The following features would represent a significant step forward in forensics investigations:

- Detect traces on-site as soon as possible (ideally in near real-time), before they degrade and loose forensic information relevant for criminal investigation.
- Perform contactless detection and analysis of various trace materials at the crime scene without any alteration.
- Perform on-site classification[2] of a wide range of traces, by exploiting finer compositional differences to push levels of specificity and discrimination toward the limits of within-source variation, based on more analytical information from the specimen itself and from a more comprehensive and relevant body of reference data.
- In order to meet the above, support various mobile - easily deployable or handheld - analytical instruments (herein also referred as sensors).
- By using and connecting multiple sensors that provide complementary and orthogonal analytical information, include data-fusion mechanisms allowing a better discriminating power of a wide set of organic, inorganic and biological forensic traces and it will allow for the gathering of more informative profiles for the investigated compounds.

Improving the CSI process and associated analytical tools will contribute to:

- Greater reliability, by relying on proven analytical methods – further improved as a result of multi-sensor data-fusion – that, in addition, are less dependent on the investigator intervention, also simplifying the steps involved in sample collection and preparation (for laboratory analysis).
- Greater efficiency, since it increases the analytical throughput (performed on-site and in near real-time) allowing a more comprehensive collection of reference data that are needed for interpretation;

[1] *Traces are the most elementary information that result from crime. Traces* [...] *need to be detected, seen, and understood to make reasonable inferences about criminal phenomena, investigation or demonstration for intelligence, investigation and court purposes*. (Margot, 2011)

[2] Trace classification is based on a comparison between the unknown specimen to be analysed and one reference sample of known origin to infer if they belong to the same class. (Champod, 2013)

- Increased scientific and legal expectations of forensic field analysis favouring new regulations and standardization.

In this work we present the Real-tIme on-site forenSic tracE qualificatioN (RISEN) project, an innovate concept in forensic investigations in the context of CSI of sites affected by a chemical, biological or explosives attack. Coordinated by the *Agenzia Nazionale per le Nuove Tecnologie, L'energia e lo Sviluppo Economico Sostenibile* (ENEA), RISEN will develop a set of network-enabled real-time contactless sensors for handling traces on site and accurate 3D recreation mechanisms of the entire crime scene, providing an immersive environment for investigators to evaluate hypotheses and conduct highly detailed investigations.

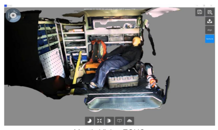
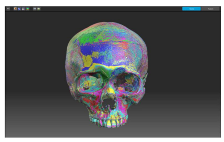
This paper is organised as follows: Section 2 presents background and related work regarding 3D reconstruction and developments in analytical tools in CSI; Section 3 introduces the RISEN system, describing its main features and components; Section 4 describes the use of the RISEN in the CSI timeline; Section 5 presents the conclusion and next steps. Acknowledgements and references are presented in sections 6 and 7 respectively.

2 Background and Related Work

CSI requires investigators to capture an accurate and objective representation of the scene. The investigator is required to recognize and collect all the physical evidence potentially relevant to the solution of the case. The underlying process is highly reliant on human perception and experience, which is also a source of potential bias. For example, during an investigation, the investigator may wrongly identify a trace as having no relevance (false positive) or discard a relevant trace (false negative) (Gruijter, de Poot and Elffers, 2017). Moreover, the analysis and positioning of all traces from a crime scene is essential to analyse the spatial distribution of the traces, to support the investigation report and ultimately to accommodate a reconstruction of the events in a crime scene. The essence of making a map of the crime scene, including the locations of all the analysed pieces of evidence, is more obvious in some cases than it is in others. For example, bloodstain pattern traces already have a visible spatial distribution (direct evidence), while for scenes containing “invisible” traces (i.e., those outside the visible spectrum), it could be essential for the investigation process to be able to spatially represent them, together with other gathered evidence. It is by now well established that passive documentation of the crime scene, such as photography alone, is insufficient.
With a rapid and contactless on-site multi-sensor analytical approach, it will become easier to detect traces (including those outside the visible spectrum) and make a reconstruction of the crime, locating identified traces in a 3D model, that can be used as a proactive investigative tool opening up a new lines of investigation.

Forensic analysis in CSI has been the subject of innovations over the last years in the field of photogrammetry, 3D reconstruction and analytical instruments. The Swedish National Forensic Centre conducted an assessment of technologies and techniques used for scene 3D reconstruction, identifying advantages and disadvantages, whose main findings are presented in Table 1.

Table 1 – 3D Reconstruction Techniques: advantages and disadvantages

Technologies		Example of analysis and visualisation	Pros	Cons
Large scale scenes (UAS camera)	 DJI Phantom 4	 Pix 4D	-Quick overview - Low-cost (many UAS available in market)	-Permissions to fly -Resolution limitation -Uncontrolled drift without reference points
Large and medium scale scenes (TLS)	 FARO Focus M70	 FARO Scene	-Fast acquisition and registration -Resolution and precision -No references needed (usually)	-Expensive -Issues with some surface materials
Detailed scenes and objects (handheld scanner)	 Mantis Vision F6 Reg and SR	 Mantis Vision ECHO	-Fast acquisition -Real time pre-registration -Precision	-Rather expensive -Issues with some materials
Small scenes and objects (SLR)	 Canon EOS 5D	 Reality Capture	-Rather fast acquisition -Cheap (already spread) -Resolution	-Difficult to validate 3D precision -Drift can occur -Comes without scale
Small scenes and objects	 iPhone 6S	 Agisoft Metashape	-Fast collection -Cheap (everyone has one)	-Resolution and accuracy -Drift -Reference points needed (risk for contamination)
High resolution details	 HP 3D Pro S3	 HP 3D scan 5	-Resolution -Precision	- Not for field use - Cumbersome setup

TLS: Terrestrial Laser Scanning, SLR: Single Lens Reflex, UAS: unmanned aerial system

SRL and cameras have been widely used in CSI, given their wide availability and accessible cost. A number of 3D scanning devices have arrived to market that are capable to deliver an accurate reconstruction of the scene, including rich visualisation tools in dedicated computers. Morgan and LaPorte (2018) analysed commercially available 3D scanners manufactured by FARO (https://www.faro.com/), Leica (https://leica-geosystems.com/), RIEGL (http://www.riegl.com/) and Zoller+Fröhlich (https://www.zf-laser.com), supported by use cases related with homicides, shootings and mass casualty events. Their impact on CSI was the following:

- 3D scanning devices enable collecting objective, durable and comprehensive evidence, significantly eliminating errors induced by human choices and reducing practices that can disturb and contaminate evidence.
- 3D reconstruction can provide valuable context to investigators, law enforcement executives and medical examiners, without needing to physically bring them into the scene and potentially compromise its integrity.
- 3D scanners typically augment testimony and other evidence related to a crime scene.

- Digital scene scans facilitate data sharing with other departments or agencies, allowing to build a more comprehensive account of the scene.
- Software enables the creation of 2D and 3D representations of the scene from the data cloud for courtroom use. The scans can corroborate other evidence, providing useful context for jurors.

Concerning past research projects, we refer to the *Forensic Laboratory for in-situ evidence analysis in a post blast scenario* (FORLAB) project[3] having as main goal to optimize the evidence collection and to reduce the time and resources in the laboratory, while preserving the chain of custody so as to minimize the time required to identify the responsible for the attack. It included: the development of analytical technologies (i.e., sensors) for in-situ sample screening, communications to connect sensors to remote centres, and a remote command and control (C2) centre with multimedia capabilities. To achieve its aims, FORLAB developed a system of highly advanced analytical forensic technologies for sample screening and 3D scenario recreation in just a few minutes. The sensors developed in FORLAB had two modes of operation: **table-top equipment** or as **backpack**. Their application was limited to post blast scene after an IED-based attack. Some of the results provided by the sensors in FORLAB were the following: The **Raman** sensor was capable of automated detection of particles of explosive with diameter of 300 μm, capability of detection of gunshot residues (GSR) on standard sampling kits and other surfaces, providing a reliable result in less than one minute. The **LIF** (Laser Induced Fluorescence) sensor was used to identify the presence of plastics and polymeric debris; detecting particles of 90 ng of explosive, or tenths of ng of explosives over a surface in just a few seconds, with **LIBS** (Laser Induced Breakdown Spectroscopy).
In addition to the analytical tools developed in FORLAB (i.e., Raman, LIBS and LIF), in RISEN the selection of sensors to develop and deploy has been expanded from the results obtained from other relevant projects like CHEQUERS[4] that developed a stand-off hand-held IR system, and ROCSAFE[5] that developed the first generation of the GC-QEPAS sensing technology used to analyze the vapour phase, FABIOLA (funded by the European Defence Agency) that developed BARDet, a biological agents detection system.
The RISEN concept merges robust detection techniques and methodologies already validated from previous FP7, EDA and NATO projects in order to meet important aspects in forensic analysis such as the demanding speed and detection requirements. Since there might be the need to screen large areas and detect and identify very low concentrations of chemical and biological traces, it is required that RISEN pushes the limit beyond the current state-of-the-art concerning the detection capabilities and analytical speed for all the developed sensors. The selected analytical sensors and visualisation approach provide a set of information that could contribute to the solution of a broad range of problems addressed in CSI.

3 The RISEN System

The RISEN project will integrate of a set of network-enabled near real-time contactless sensors for the optimization of the trace, detection, visualisation, identification and interpretation on site, combining 3D scene reconstruction capabilities and digital evidence management.
The objectives of the RISEN project will be obtained by:

- **Developing and demonstrating remote, non-destructive, automated sensors** (i.e., Raman, IR, LS-LIF, HSI – see Table 2) to **identify, select and label trace materials quickly, reliably, and on site**. RISEN contactless analytical elements will complement

[3] https://cordis.europa.eu/project/id/285052
[4] https://cordis.europa.eu/project/id/645535
[5] https://cordis.europa.eu/project/id/700264

(even replace) traditional investigative methods, requiring trace sampling and laboratory analysis.

- **Obtaining a deeper trace profiling by deploying remote but destructive sensors** (i.e., LIBS and IMS – see Table 2) in the order of micrograms (case of LIBS) and nanograms (case of IMS that, depending on the desorption method, it may be considered non-destructive or destructive technique);
- **Providing a fast and accurate 3D reconstruction of the entire crime scene** - resorting to 3D scanning capabilities and application of augmented reality techniques displaying sensor data, collected evidence and identified points of interest - to deliver a realistic and immersive visual environment for investigators.
- **Gathering information from networked sensors**, including position and labelling of the identified and classified traces and relative results of the on-site analysis, to build a "**3D Augmented" Crime Scene Investigation (CSI)**, running on-site, on mobile and/or portable units, or remotely, on specialised workstation computers at headquarters. Using the reconstructed 3D scene, it delivers information in an immersive user-friendly way, allowing investigators to evaluate hypotheses and conduct highly detailed investigations;
- **Implement mechanisms for security and admissibility of (digital) evidence** over the Chain-of-Custody, by assuring **integrity** (assurance that the evidence is not altered or tampered with throughout the whole investigative processing chain); **traceability** (guaranteeing that exchanges associated with the evidence are registered); and **acceptability** (follow EU and national legal and criminal procedural frameworks). The **crime scene, and the related analytical information obtained from the traces, will be digitally frozen**, becoming available for investigators and other stakeholders.

RISEN can be depicted as comprising three main layers as shown in Figure 7.

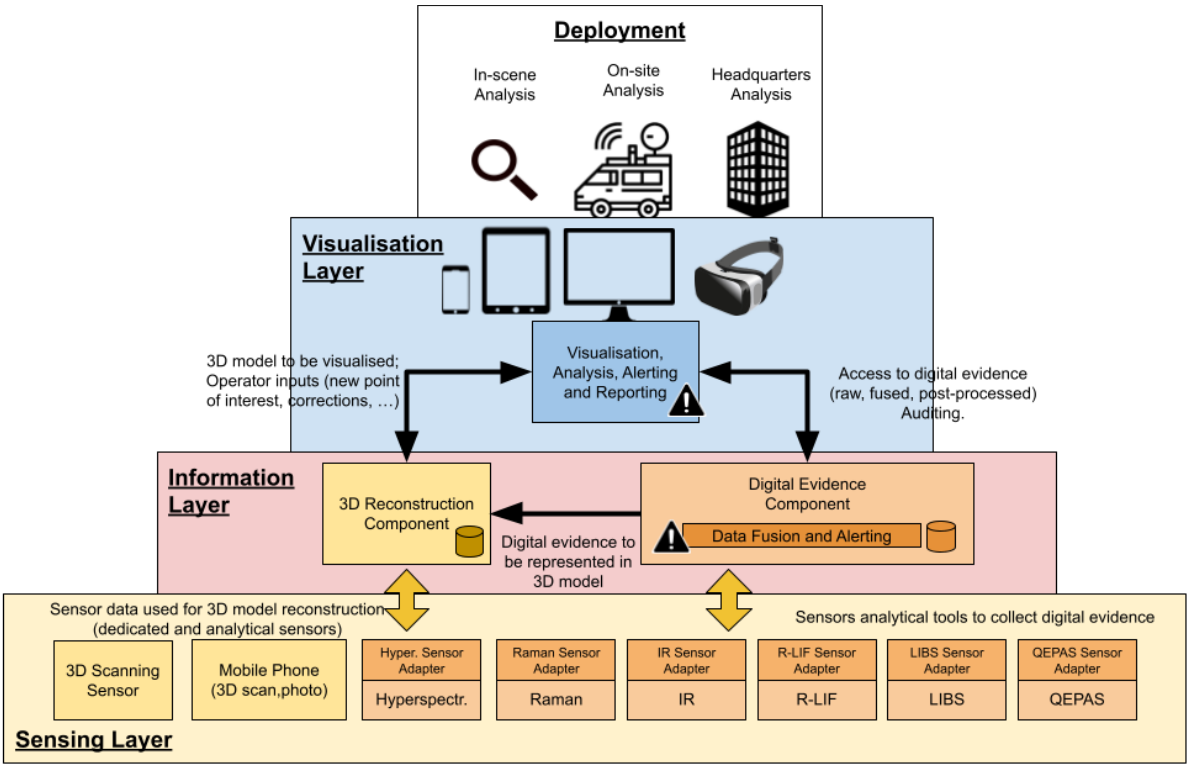


Figure 1 - RISEN system layers

The **sensing layer** deals with the various sensors and analytical tools that can be used in forensics investigation. RISEN adopts a modular approach allowing to connect different analytical tools, according to the needs of a specific investigation scenario. The RISEN modular approach is enabled by means of an open API, defined specifically for this project, that will be supported by each sensor manufacturer.

The **information layer** comprises components that deal with information management and processing. It has the following main components: The **3D Reconstruction Component** that creates a 3D model of the crime scene from dedicated 3D scanning sensors and applicable analytical sensors. This component is further described below; The **Digital Evidence Component** that handles the collection, integration and fusion of data collected by analytical tools. The component connects and interfaces with various sensors in a modular and harmonised way, benefiting from a sensor API to be developed as part of the project. This component also ensures data security and integrity of all connected data. It is further described below; The **Data-Fusion and Alerting Component** that processes and correlates complementary and orthogonal analytical information from multiple sensors, by means of an expert system for pattern recognition on the data collected by each sensor of a network, estimating the probability of each target by each sensor (Ferrari, Ulrici and Romolo, 2017). Alerts are generated based on pre-defined conditions.

The **visualisation layer** deals with the presentation of information to investigators, in an intuitive and immersive way. This layer includes 3D scene visualisation and augmented reality techniques using VR-headsets and mobile phones or high-resolution displays. Collected forensics data from analytical tools (sensors) are overlaid in the 3D-model and presented as a part of augmentation. This layer also displays alerts and notifications to the users (using various pre-defined channels, such as screens, mobile phones, emails, etc.). Moreover, this layer provides investigators with capabilities to visualise and analyse forensics data collected from analytical tools including results from data fusion, and visualising spatial correlations, allowing inspecting each step of the process and revert it if needed.

The RISEN main components are described next.

3.1 RISEN Sensors

RISEN is based on an active holistic case management for the qualification of forensic traces in a real-time and a contactless manner. In RISEN, sensor technologies will be developed in a way that it will result in their most effective and appropriate use within forensic activities, meeting scientific practices. Table 2 presents the RISEN sensors together with their respective application in forensics investigations.

Table 2 - List of RISEN tools and their application in the forensics field

RISEN Sensor	Application in Forensic Investigations		
	Chemical evidence	Biological evidence and biological agents	Comments
QEPAS Sensor	Volatile constituents of evidence;	-	Protection of operator against health and safety hazards (chemical threats)

BARDet - BioAerosol Detector	-	Any bioaerosol in the air, which may pose a threat to personnel at the scene.	Protection of operator and personnel against health and safety hazards (airborne biothreats)
LS-LIF Sensor (1), (5)	Change of type of material (example: IED components, glasses, etc.) On solid targets: Localization of Explosives, gunshot residues, body fluids, etc.	Any trace material on a solid surface	Identification of traces trough material change (substrate and residues) and surface state (roughness and reflectivity). Discrimination of liquid residues (lower signal scattering compared to the substrate) from powder ones (increased scattering).
Raman Sensor (1)	Drugs, explosives, gunshot residues, fibers, paints, varnishes…	Body fluids: blood, saliva, semen, sweat, vaginal fluid. Dating of blood (possibly).	Raman is very selective but due to the intrinsically low signal, requiring long exposure time, it will be performed in points selected by fast LS-LIF scanning.
IR Sensor (1)	Drugs, explosives, gunshot residues, fibers, paint, common false positives during blood residues (paint, coffee, soda).	Body fluids: blood, semen, vaginal fluid, urine. Dating of blood.	Stand-off, highly selective and real-time identification of body fluids. Compatible with Hyperspectral imaging. Distinction between human and animal blood.
LIBS Sensor(2)	Explosives, gunshot residues, earth material, glasses, paints	Presence (YES/NO) of body fluids	The technique does not discriminate type of explosive or fluid but is very sensitive to indicate their presence. It will be applied at some points selected by fast LS-LIF scanning.
IMS with surface desorption capability (3)	Traces of drugs, explosives and hazardous material detection and identification.	Volatile/Semivolatile evidences material, presented on scene of crime, identification based on fingerprint.	The technique can allow to detect traces of chemicals on the surface and in most cases discriminate type of drugs or explosives. Depending on the desorption method it may be considered either non-destructive or destructive technique. Amount of detected material is dependent on the material and surface properties.
Hyperspectral imaging (HSI) (1), (4)	Drugs, explosives.	Body fluids: blood, semen, vaginal fluid, urine. Dating of blood.	Fingerprints identification as long as there is a contrast between the fingerprint and the surface. Identification of the distribution of stains (mixtures of body fluids).
3D Scanner	-	-	Crime scene 3D reconstruction and morphological analysis.

(1)Non-destructive technique; (2)Micro-destructive technique (1µg per analysis); (3)Non-destructive or micro-destructive technique (nanograms); (4)UV-Vis range (400-1000nm), NIR range (1000-2500nm); (5) LS: Laser Scattering, LIF: Laser Induced Fluorescence

The wide variety of sensors makes RISEN potentially applicable to all conventional forensic scenarios (e.g. homicide, clandestine laboratories) and those related to chemical, biological and explosives incidents.
RISEN adopts a modular network-enabled approach to seamless connect one or more sensors. For this purpose, it will define a generic API that will be extended and supported by each sensor manufacturer, as depicted in Figure 2.

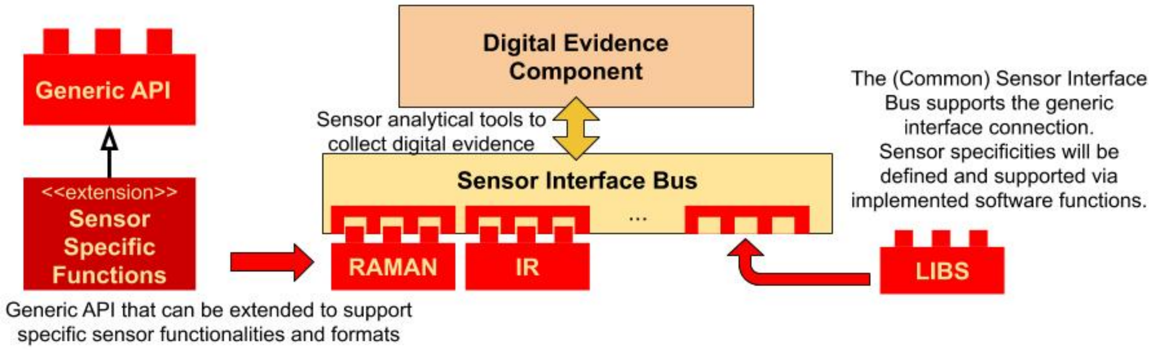


Figure 2 - RISEN API: A modular approach to integrate sensor's data

RISEN's generic API specifies a sensor's common functions, including metadata (specifications and features), protocols and data formats. Then, the generic API is extended by implementing the specific functions of a sensor, including information relevant for 3D representation. This approach allows the implementation of a sensor interface bus supporting the common sensor API (and connector) that seamlessly connects various sensors. The connection will be network-enabled, supporting Internet-based technologies (for maximum interoperability and compatibility) – including use of IP protocol and TCP/UDP for data exchange and RTP for multimedia streams – and will be realised via wired (e.g., UTP or optical cable) or wireless (e.g., IEEE802.11n/Wi-Fi) connectivity.
Enabled by the generic API, RISEN modular approach allows the system to be customisable to meet the needs a specific forensic customer, by adding or removing sensors. Even if the analytical power of the RISEN system is at its peak when all components are used, it is still possible to deploy tailored versions of the system (i.e., a sensor subset) – for instance, when a crime scene analysis only requires a reduced set of sensors – under the same operational software. The selection of tools to use on the field will depend on the investigator' needs and, ultimately, on the tools they have available due to budget constraints.

3.2 Digital Evidence Management and Chain-of-Custody

RISEN brings a "digital evidence management" component that handles collection, storage and access of the relevant data generated by sensors, the data-fusion process and investigators (e.g., annotations). RISEN generated data is labelled, stored and, where applicable, located in the scene.
This component also implements mechanisms assuring security and admissibility of (digital) evidence over the Chain of Custody, by providing **integrity** (assurance that the evidence is not altered or tampered with throughout the whole investigative processing chain); **traceability** (guaranteeing that exchanges associated with the evidence are registered, ensuring full auditability); and **acceptability** (follow European and national legal and criminal procedural frameworks). Confidentiality is assured by using encryption and authentication, with implementation of attribute-based access control (ABAC) to grant access rights. The component receives digital evidence (resulting from tagging and data fusion) and stores it in the evidence database (only write and read operations), while generating a cryptographic hash function (using e.g., SHA-3) - that is a unique hash value related to the evidence data – and

stores it in the integrity database, a persistent database that allows write and read operations, but does not allow modification or deletion operations. When retrieving data, an integrity check is performed by verifying that the stored hash value matches the hash generated from the retrieved data. Updates to evidence data generate a new entry in the evidence database and a new hash value.
Auditing mechanisms will be implemented allowing the tracking of all data operations (e.g., CRUD: create, read, update, delete) over the data lifecycle, capturing relevant context information (who, what, where, when, why).

3.3 3D Reconstruction and Visualisation

RISEN includes the capability to create a 3D model of the crime scene. The reconstruction utilises a 3D scanning device for creating an accurate and detailed 3D representation of the crime scene. In addition, photos collected from *e.g.* a mobile phone can be used to complete or further enrich the 3D model, especially in occluded areas. RISEN will focus on creating methods for fusing 3D data from multiple sources as automatically as possible as well as create tools to automatically register location aware sensor data to the correct position in the 3D model.
Figure 3 shows an example of a 3D scanned indoor scene from a double homicide in 2017 where an elderly couple was murdered. The 3D-documentation of the crime scene was performed six months after the event. The bodies were moved but the kitchen was left almost as it was at the time of the CSI, hence the blue artificial bodies in the visualization. The 3D model allowed investigators (and other stakeholders) to conveniently browse and navigate the scene, without risking compromising a scene's integrity.

Source: Swedish National Forensic Centre

Figure 3 – Example of a 3D scanned crime scene visualizing the placement of the bodies

A more elaborated setting conducted by the Swedish National Forensic Centre consisted in the forensics analysis of the terrorist attack in Stockholm in 2017. As illustrated in Figure 4, the centre recreated the steps taken by the terrorist driving a lorry, by resorting to a 3D reconstruction of the outdoor scene (more than 1000 meters of city streets), requiring 97 scanning points and about 6 hours to collect data[6].

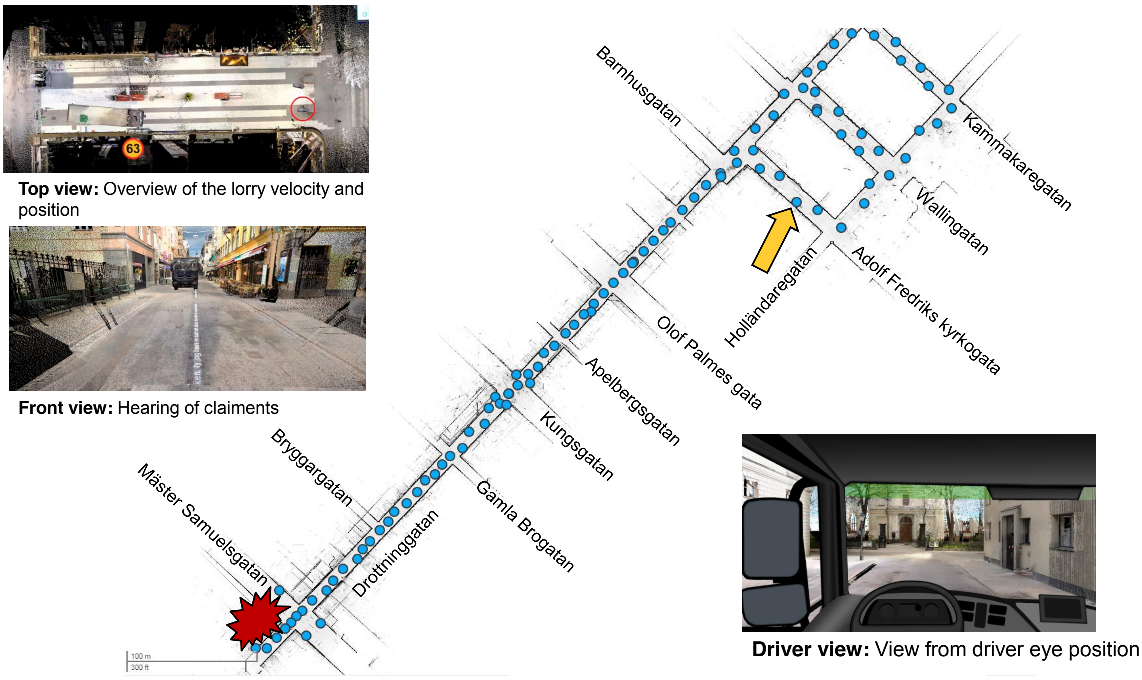


Figure 4 – 3D reconstruction and simulation of the terrorist attack in Stockholm in 2017

Complementing 3D scanning, RISEN will integrate data from sensors into the generated 3D model, aiming to further enrich and improve the potential outcomes that investigators can take from a truly immersive environment for forensics investigation. Position sensitive sensors will be equipped with a camera and the camera view will be calibrated with the sensor view. 3D environment of the sensor view is reconstructed with photogrammetry methods. Sensor data is mapped to the 3D model by finding a best match with the location in the 3D crime scene model and sensor camera created model. When the best match is found, the sensor measurement data is registered to the 3D model into corresponding position.

Spatially mapped sensor data will be presented to investigators. Two key aspects are herein outlined: in case of “invisible” traces (outside the visible spectrum), investigators can now “see” them in the “augmented” scene; investigators will be able to visualise data from several sensors and results from data-fusion in the “augmented” scene.

It is also important to acknowledge the different data hierarchy levels for examining the crime scene generated in RISEN: raw sensor data; processed sensor data (e.g., trace classification); and relationships between data (e.g., sensor fusion and spatial correlation). Via “scene augmentation”, investigators will be able to understand the relationships between different measurement results and conduct a comprehensive analysis and investigation.

An illustrative example of “RISEN in action” is given in Figure 6.

[6] The video is accessible at: https://www.youtube.com/watch?v=ObOwigXByMo

4 RISEN in Action in a CSI Timeline

The approach proposed in RISEN will be applied in classical forensic investigations, as well investigations of sites that were damaged as a result of a CBRNe event, such as Improvised Explosives Device (IED) triggered by criminal or terrorist activities. In this chapter, we present a possible application of RISEN throughout the timeline of a CSI, also illustrated in Figure 5.

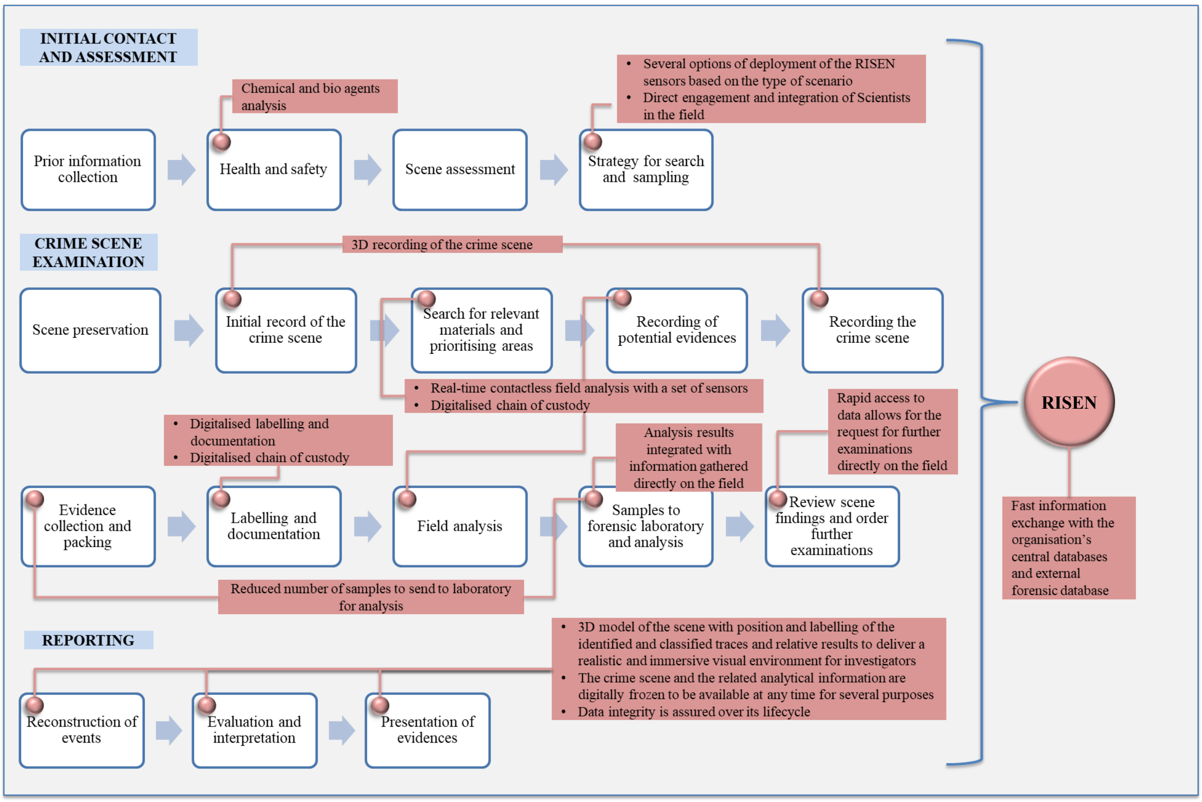


Figure 5 – RISEN Role in the CSI Timeline

Following the occurrence of an incident involving the use of IED, investigators have an **initial contact with the scene**, evaluating the scenario and defining the analysis strategy, having access to a wide range of RISEN sensors.

In order to prevent personnel from being exposed to various health and safety hazards arising from a number of sources including chemicals or biological materials, investigators first assess if the scene is safe by deploying the **QEPAS and the bioaerosol detector**, which will detect the presence of biological agents and chemical agents.

The **crime scene is examined**, using the **QEPAS sensor** that also provides fast detection and identification/classification of chemicals in vapour phase, thus gathering information about the volatile constituents of the forensic evidence. If not performed rapidly (on-site), volatile constituents might otherwise disappear rapidly from the scene and remain undetected. Identification/classification of volatiles might allow, for example, to trace back the solvents or catalysers utilized in the synthesis of toxic or explosive material, and establish correlation between a specific trace found on a crime scene, with traces found by other inquirers on other scenes.

A **3D model of the scene** is created using a **3D scanning device**. In parallel, the **LS-LIF sensor** is used to perform a scanning of the scene for detecting the material change (substrate and residues) from one scanning point to another. The LS provides information about the surface state (roughness and reflectivity) and, in combination with LIF, it discriminates liquid residues (lower signal scattering compared to the substrate) from powder ones (increased

scattering). The LS and the LIF point resolution depends on the distance and focusing and for LIF it could be < 1mm for working distance <10 m. The LS-LIF image can be superposed in the 3D model or with photograms taken by a standard camera.
The 3D initial reconstruction is extended by scanning the scene with **hyperspectral imaging (HSI)**, in such a way that useful chemical information is recorded for each pixel. This enables a preliminary chemical screening of large surfaces in the scene with the aim of locating macroscopic, millimetric and microscopic traces (down to 15 µm size). HSI working in the near infrared (NIR) range (i.e. 1000-2500 nm) is especially selective since the chemical identification/classification is based on the first overtone and first combination region of those (C-H, N-H and O-H) molecular vibrations whose fundamentals enable the specific chemical characterization and IR fingerprint of organic chemical compounds. Thus, NIR-HSI is highly useful for locating relevant chemical evidence (including drugs and explosives), and biological evidence (including stains of body fluids).
After the preliminary HSI chemical screening, the scene is searched systematically and thoroughly for relevant traces using alternatively the scanning **Raman and IR sensors** that can be deployed in different ways based on the request of the operators and the accessibility of the crime scene (via e.g., tripod or unmanned vehicle) to detect several types of traces (e.g., body fluids, dating of blood) in the order of few µg/cm (Chirico et al., 2016; Khandasammy et al., 2018). The combination of both IR and Raman sensors ensures that practically all substances can be identified, since IR-problematic aqueous samples can be analysed by Raman spectroscopy whereas Raman-problematic fluorescent samples can be analysed by IR spectroscopy.
Contactless spectroscopic instruments for detection of forensic materials by vibrational spectroscopy, like Raman (Muro et al., 2015), IR (Carson et al., 2018), LIF (Miranda, 2014) and LIBS (Hark et al., 2014) techniques are generally used separately and for short target distances except in case of a few, non-commercial instruments operating remotely (>2m) and mainly tested for individuation of explosives or IEDs. Fusion of these sensors for remote measurements, which might cover a wide range of different applications and scenarios including detection of traces in wide areas, are presently achieved only by NASA (Perez, 2016) and ENEA (Lazic et al., 2017).
The detection of the chemical traces, including drugs or explosives, on the surfaces is not an easy process and often will require swiping multiple surfaces and analysis of collected samples. Therefore, potentially advantageous can be use of **Ion Mobility Spectrometer (IMS)** with surface desorption capability[7], which will allow for contactless identification of the spots with chemical evidence traces.
The processed data from sensors are collected separately and integrated by the RISEN system in the 3D reconstructed model of the scene, and, at the same time, the analytical results are shown to investigators to minimise the false interpretation of traces maximising the detection probably and to gather more informative profiles from the investigated traces.
For instance, RISEN exploits emerging NIR, IR and Raman spectroscopic techniques applied for the forensic analysis of body fluids (blood, semen, saliva, urine, vaginal fluid or sweat), due to their high potential to identify and differentiate body fluids directly on-site prior to DNA extraction. Nowadays, one of the principal lines of active research in body-fluid classification is based on the use of NIR, IR and Raman spectroscopic analytical techniques (Morrison et al., 2015, Zapata, de la Ossa and García-Ruiz, 2015).

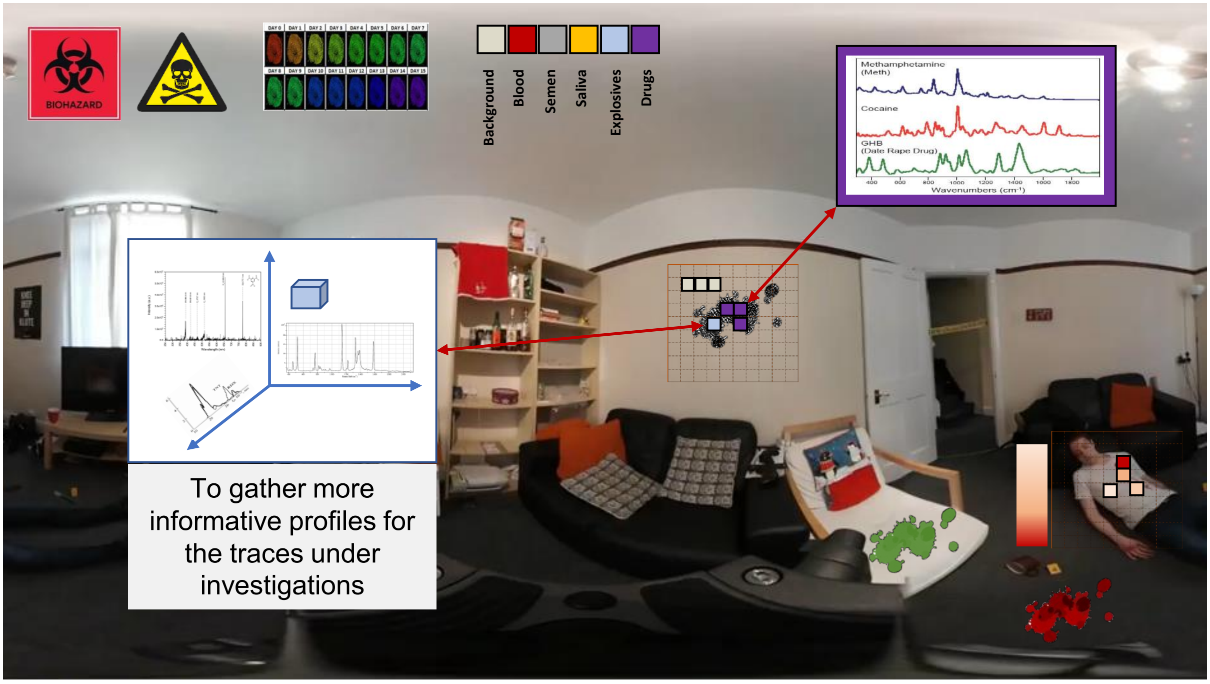
[7] Most of the commercially available sensors require collecting samples (i.e. swiping before an analysis can be performed). The proposed IMS system with surface desorption capability will allow performing traces analysis from the surface without direct physical contact.

Following the examination of the first results, the investigator is supported and guided by the user-friendly interface of the RISEN system to better identify the traces that are required to obtain meaningful results for interpretative purposes from the large number of forensic exhibits. The investigator can also assess if any additional examinations of the scene are required. For example, in case the Raman and IR sensors failed to detect residues due to insufficient sensitivity, or it is necessary to identify additional classes of traces. In this case, the **LIBS sensor** can be deployed at selected points. The LIBS sensor provides elemental composition information at concentration levels that allow significant sample discrimination also among tiny residues in a solid surface. This technique typically consumes less than 1 µg for analysis and inside the spot of < 1mm diameter, therefore samples are not completely destroyed and allow subsequent sampling. Sensitivity down to ppb level provides criminologists with the scientific information to determine how trace evidence could relate to each case.

For legal purposes, in order to maintain the chain of custody, all the identified traces are digitally labelled. Each label contains information about the trace and its handling (the name of the operator who has run the instrument, date and time when it was discovered, position and picture of the location, analytical information, etc.).

At the end of the analytical analysis, RISEN provides a comprehensively digitalised documentation of the crime scene with all the relevant information in a clear, concise, structured and unambiguous manner in accordance with available international standards[8]. The documentation can be tailored by the requirements of the criminal justice system for the country of jurisdiction.

An illustrative and fictional example of the results produced by RISEN is provided in Figure 6. The figure illustrates a 3D reconstructed scenario "augmented" with localised sensor data, including resulting from data-fusion.



Notes: Fingerprint image (on top) is taken from (Cadd et al., 2019).
Background image is retrieved from https://www.youtube.com/watch?v=9u5YnyApsCE

Figure 6 - RISEN in Action

[8] Conformity assessment - Requirements for the operation of various types of bodies performing inspection, ISO/IEC 17020, 2012.

The RISEN concept will allow forensics investigators and judicial authorities, to gather high quality information from a vast list of visible and invisible traces (localisation, identification/classification, interpretation and labelling) from a crime scene through standardised reports and a secure way.

5 Conclusion

Supported by the European Commission, the RISEN project started in July 2020 and is planned to run for four years. Based on the range of possible forensic approaches on the field, the key elements resulting from RISEN include:

- Applicability to a variety of types of national and international crime scenes;
- An important timespan reduction in trace analysis and crime scene investigation, without forgetting the health and safety of operators;
- A methodology that will allow for preliminary examination of complex trace evidence mixtures for the recognition of traces of potential investigative or evidential significance;
- A methodology that will help include/exclude sources and identify possible links through data fusion;
- A system that is modular and adaptable, capable to meet a wide range of needs;
- Digital-enabled, allowing fast integration and exchange of information between investigators, trace evidence analysts and specialists, enabling timely, focused analytical requests and communication of findings;

During its execution, the RISEN project will provide several advances beyond the state of the art in the forensics investigation field, including real-time contactless trace analysis directly *in situ*, data-fusion mechanisms and evaluation through an innovative easy to use 3D “Augmented” Crime Scene Investigation system. Highly innovative contactless sensor prototypes for chemical and biological analysis will be delivered. The RISEN system modularity will allow investigators to select and deploy the appropriate set of sensors, in order to meet the investigation needs.

The varied and integrated analytical approach will allow for the detection, visualisation, classification and individualisation of a wide variety of traces (visible and invisible). As a result of gathering analytical information about traces directly on the scene (performed *in situ* and in near real-time,), the RISEN system will reduce the need to send samples to laboratories for further analysis. Therefore, the RISEN system will speed-up the forensic investigation process.

Moreover, the data acquired by 3D scanning the scene and by the contactless sensors will be fused by the RISEN system blended with integrated robust cryptographic systems and capacities to ensure the chain of custody integrity and the legal value of the evidence.

Using 3D scene “augmentation” tools, RISEN provides an immersive environment for investigators to evaluate hypotheses and conduct highly detailed investigations. 2D and 3D representations of the scene can also be created to support cases in courtrooms.

Finally, RISEN will propose and contribute to new standards for analytical methodologies, protocols, training, and quality management in order to meet the increasing legal and scientific expectations in trace qualification.

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