On the Path Towards Standardisation of a Sensor API for Forensics Investigations

Marco Manso[1][a], Bárbara Guerra[1], Fernando Freire[1], Roberto Chirico[2], Nicola Liberatore[3], René Linder[4], Ulrike Schröder[4] and Yusuf Yilmaz[4]
[1]*Particle Summary, Lda., Lisbon, Portugal*
[2]*Diagnostic and Metrology Laboratory, ENEA C.R., Frascati, Italy*
[3]*Research & Development, Consorzio C.R.E.O., L'Áquila, Italy*
[4]*Standards Committee Medicine, German Institute for Standardization (DIN), Berlin, Germany*

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Abstract: Forensics investigations need to be conducted efficiently and accurately especially in situations where time is a scarce resource. Novel technologies, like forensic sensors, can aid investigators in trace detection, visualisation, identification and interpretation on site. Arising from the need to connect different sensors to a remote digital management software, a network-enabled Sensor API is proposed to enable any compliant CBRNe Sensor to connect and exchange information in a harmonised and interoperable way. As a result, a Standardisation Workshop agreement, on CBRNe SENSOR API - Network Protocols, Data Formats and Interfaces, was initiated to promote standardisation of the Sensor API. The new proposed standard will allow sensor manufacturers to focus on sensor development work, benefitting from already defined interfaces and data models. Moreover, forensic investigators, acting as end-users, can better understand and analyse (well defined) sensor outputs, thus improving their work efficiency and facilitating technology acceptance.

1 INTRODUCTION

Crime scene investigation (CSI) involves careful and thorough observation of crime scenes to identify and collect forensics evidence potentially relevant to the solution of the case. It is important that the investigation is performed efficiently and accurately, since it will allow directing subsequent law enforcement actions towards well identified individuals or groups, supported by the collected evidence and under the rule of the law.

Over the years, CSI methods, technologies, tools and procedures have greatly evolved, accompanying scientific breakthroughs (e.g., DNA profiling), paving the way for the creation of the forensic science field. Technologies, in particular, have been developed to make the CSI process faster and safer for investigators, without compromising reliability.

While investigators have tools to use on-site (e.g., multispectral cameras, 3D scanners, drug kit tests), they still depend on laboratorial analysis, as the "golden standard", for classification and identification of traces [2] (e.g., drug profiling, fingerprint identification) and producing court admissible evidence. Notwithstanding, the laboratory analysis process may result in the destruction of the sample and can be lengthy, usually taking several hours or days. Time becomes a scarce resource, especially in crime scenes where preserving traces is challenging, such as outdoor environments or hazardous environments, contaminated by dangerous biological or chemical agents.

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[a] https://orcid.org/0000-0003-0953-049X

[2] *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)

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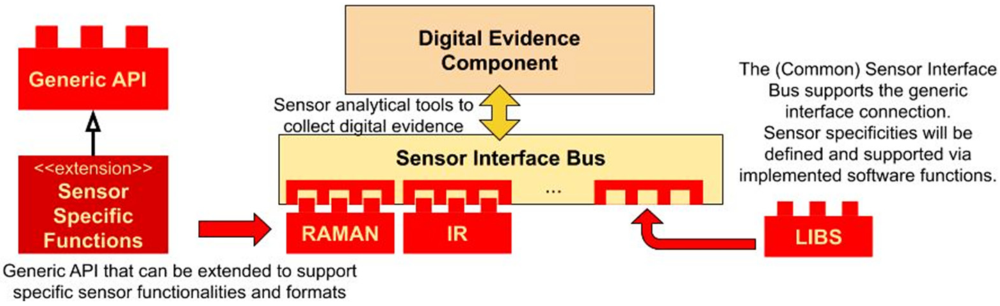

Figure 1: RISEN API: A modular approach to integrate sensor's data.

Hence, the following features would represent a significant step forward in forensics investigations (Manso *et al.*, 2020):

- 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 risking compromising their integrity.
- Perform on-site classification[3] 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, several mobile analytical instruments (herein also referred as sensors) that are easily deployable or handheld have been developed, providing novel capabilities in forensics investigations. Being a novel field, the lack of available standards results in manufacturers following their own implementation path, which in turn results in non-interoperable sensors that negatively impact on the efficiency of what is by nature an already time-consuming activity.

This paper introduces the work developed as part of the European Action Real-tIme on-site forenSic tracE qualificatioN (RISEN)[4], with the support of the German Institute for Standardization (DIN), in identifying and promoting new standards in forensic sciences, particularly, in the definition of a sensor Application Programming Interface (API) enabling different forensics sensors to communicate in a consistent and harmonised way with a remote server, using widely used web-based technologies.

The remainder paper is structured as follows: Section 2 presents the RISEN project, being an innovative approach for conducting on-site CSI based on 3D scene reconstruction and use of interoperable sensors for identification of traces; Section 3 describes the sensor API enabling sensor interoperability, starting from the concept, followed by core technologies, and sensor data model. The section also presents possible deployment options, enabled by the Sensor API, and preliminary results attained in RISEN; Section 4 introduces the standardisation efforts already initiated for the Sensor API; Section 5 concludes this paper.

2 RISEN: ON-SITE SENSORS SUPPORTING FORENSICS INVESTIGATIONS

The RISEN project introduced an innovate concept in forensic investigations in the context of CSI on sites affected by chemical, biological or explosives attack. Coordinated by the *Agenzia Nazionale per le Nuove Tecnologie, L'energia e lo Sviluppo Economico Sostenibile* (ENEA), the RISEN aim is to develop a set of sensors for the optimisation of the trace detection, visualisation, identification and interpretation on site, with a consequent reduction of the time and resources in the laboratory. RISEN started in 2019 and is planned to be finalised in 2024.

In the RISEN project, several network-enabled real-time contactless sensors for handling traces on-site are being developed. Moreover, using commercially available 3D scanning technologies, RISEN is also allowing the generation of an accurate 3D recreation of the entire crime scene, integrating information collected by sensors and providing an immersive environment for investigators to evaluate

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[3] 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)

[4] RISEN has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 883116.

hypotheses and conduct highly detailed investigations.

Table 1 presents the RISEN sensors together with their respective application in forensics investigations.

All sensors developed in RISEN are connected to a server software system (i.e., the 3DA-CSI System) that receives and manages data sent by sensors, via a Digital Evidence Management component. Since its inception, the concept of a modular network-enabled approach that seamless connect the different RISEN sensors was envisaged. This approach led to the creation of the RISEN Sensor API, described next.

Table 1: List of RISEN sensors and their application in the forensics field (Manso *et al.*, 2020).

RISEN Sensor	**Application in Forensic Investigations**	
	Chemical evidence	***Biological evidence and biological agents***
GC-QEPAS Sensor	Volatile and semivolatile constituents of evidence.	-
BARDet - BioAerosol Detector	-	Any bioaerosol in the air, which may pose a threat to personnel at the scene.
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
Raman Sensor (1)	Drugs, explosives, gunshot residues, fibers, paints, varnishes…	Body fluids: blood, saliva, semen, sweat, vaginal fluid. Dating of blood (possibly).
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.
LIBS Sensor(2)	Explosives, gunshot residues, earth material, glasses, paints	Presence (YES/NO) of body fluids
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.
Hyperspectral imaging (HSI) (1), (4)	Drugs, explosives.	Body fluids: blood, semen, vaginal fluid, urine. Dating of blood.

(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

3 RISEN SENSOR API

This section presents the concept behind the sensor API, followed by the selected enabling technologies, the sensor data model, deployment options allowed by the API and preliminary results from a RISEN sensor in using the API.

3.1 Concept

The RISEN Sensor API was implemented by PARTICLE Summary to define a consistent and harmonised way for sensors to connect and send information to a server system. The Sensor API is depicted in Fig. 1.

The sensor API concept includes a server-side component and a client-side component. The client-side component comprises a "Generic API" that defines general functions to be supported by a RISEN sensor, such as registration, connection, reporting status and sending measurements. Sensor specific functions can be implemented by extending the "Generic API", while keeping compatibility with the RISEN System.

The client-side component connects to the server-side component that, via the “sensor interface bus”, sends sensor data to the RISEN 3DA-CSI System.

The server-client connection supports Internet-based technologies for maximum interoperability and compatibility, including the use of the Internet Protocol (IP) and the Transmission Control Protocol (TCP)/User Datagram Protocol (UDP) for data exchange, and is realised via wired (e.g., Unshield Twisted Pair (UTP) or optical cable) or wireless (e.g., IEEE802.11ac/Wireless Fidelity (Wi-Fi)) connectivity. Clients can access the server API using the server's Uniform Resource Identifier (URI).

3.2 Core Technologies: HTTP, JSON and REST

The approach for the RISEN Sensor API is based on open-source and widely used technologies and it follows the REpresentational State Transfer (REST) architecture. The client-side component can send requests to the server-side component through the server URI, using the Hypertext Transfer Protocol (Secure) (HTTP(S)) protocol, including payload data typically formatted as JavaScript Object Notation (JSON), eXtensible Markup Language (XML) or plain text. The API favours the use of JSON for payload data.

In RISEN, the HTTP protocol is used, including the methods described below (as per RFC7231[5]):

- GET can be used to request transfer of a current selected representation for the target resource. It is the primary mechanism of information retrieval.
- POST requests that the target resource processes the representation enclosed in the request. It is typically used as a mechanism to upload information.
- PUT requests that the state of the target resource be created or replaced with the state defined by the representation enclosed in the request message payload.
- DELETE requests that the origin server removes the association between the target resource and its current functionality.

Each HTTP request produces a status code indicating if the request was successful or if an error occurred. The status codes are categorised as follows:

- 1xx (Informational): The request was received, continuing process.
- 2xx (Successful): The request was successfully received, understood, and accepted.
- 3xx (Redirection): Further action needs to be taken in order to complete the request (i.e., the operation should be retried).
- 4xx (Client Error): The request contains bad syntax or cannot be fulfilled (e.g., bad request or unauthorised request).
- 5xx (Server Error): The server failed to fulfil an apparently valid request.

3.3 Message Broker for on-Event Processing

The publish-subscribe paradigm enables on-event processing as a result of its capability to push messages to clients, meeting known criteria. The publish-subscribe paradigm implies the existence of different roles:

- a publisher, which produces messages,
- a subscriber, which consumes messages, and
- a message broker, which gathers and distributes the messages from publishers to subscribers.

The protocol is well suited to disseminate sensor information, so it is a widely-used protocol in network-enabled environments. Within the RISEN Sensor API, the publish-subscribe paradigm complements the REST architecture in the sense that the latter is reactive (responds to the client or server requests) while the former is proactive (on event, notifies subscribers of new messages).

The lightweight Message Queuing Telemetry Transport (MQTT), standardised as ISO/IEC PRF 20922 (ISO, 2016), was selected as the message broker for the Sensor API.

3.4 Sensor Data Model

The RISEN Sensor API also defines the necessary data models used in information exchange. The data model includes the “Sensor” group that contains entities representing sensors and sensor-generated data. The sensor entity together with other relevant entities are presented in Fig. 2.

A sensor is represented in the “Sensor” entity.

The "SensorEvent" entity represents the basic information structure related to dynamic sensor data. It is extended by: “SensorStatusEvent” entity, that refers to sensor status information, usually operational status and battery level; and “BaseMeasurementEvent” that includes the various supported sensor measurements (e.g., detection, category, timeseries data). Thus, two entities, with several sub-entities associated, "extend" the SensorEvent, inheriting its fields and adding new ones to address needed specificities. Thus, a sensor can generate multiple SensorEvents.

3.5 Deployment Options

The network-enabled architecture selected for the RISEN System and the Sensor API, supported by widely adopted and open web-standards, delivers a high degree of flexibility concerning the deployment options for the RISEN System in operational environments.

This subsection presents the deployment options for the RISEN System, allowing to meet most end-user scenarios.

3.5.1 RISEN Deployment at the Crime Scene

In this setting, the RISEN System is transported and installed at the crime scene. This includes all RISEN sensors and the 3DA-CSI System. A local network (wired or wireless) is established to connect all RISEN modules. The RISEN sensors send measurements to the 3DA-CSI System. The investigator accesses the 3DA-CSI System locally, using a computer or a mobile App. All information is locally stored in the 3DA-CSI System.

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[5] https://tools.ietf.org/html/rfc7231

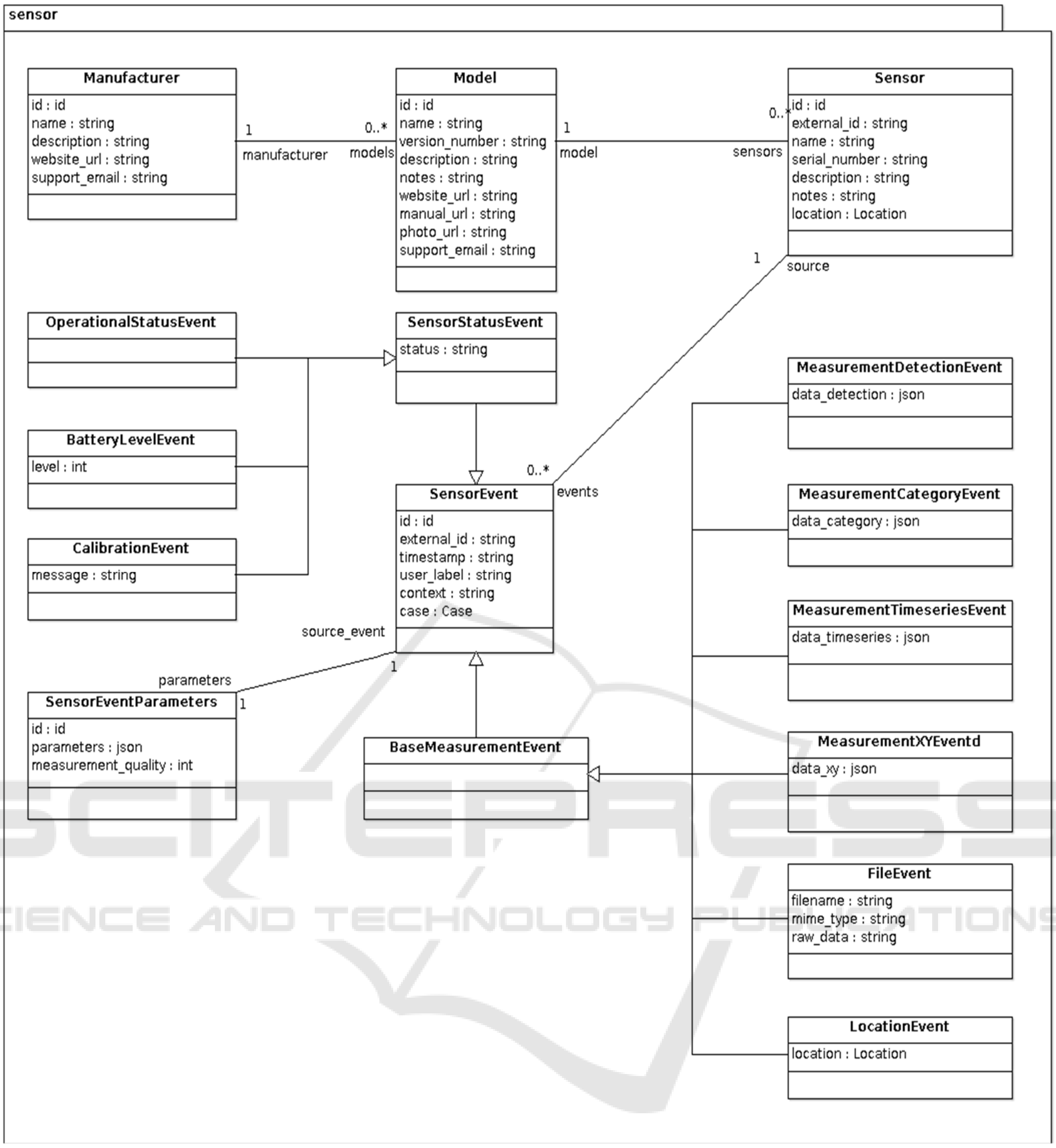

Figure 2: Sensor data model (preliminary).

In this setting, illustrated in Fig. 3, it is not possible to remotely access information from the 3DA-CSI System (e.g., request assessment from an expert not located at the crime site). Users can export all gathered data to a central 3DA-CSI System *a posteriori*, using the RISEN 3DA-CSI System's export/import functions. It is advantageous for situations where network connectivity with a central 3DA-CSI System is not possible (or desired). However, the setting also limits the availability of gathered data in near-real time to investigators on-site only. Moreover, the 3DA-CSI System should be running on a portable device, with limited processing capabilities.

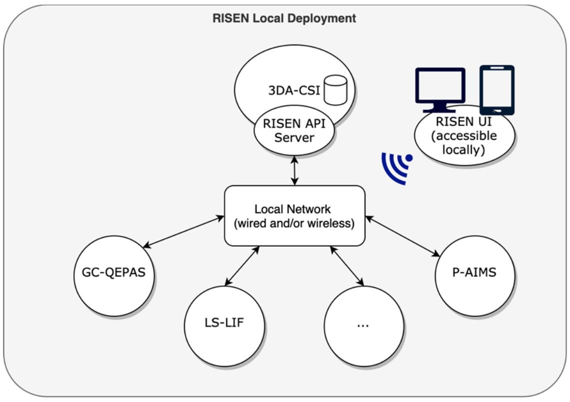

Figure 3: Local Deployment.

3.5.2 RISEN Deployed in a Vehicle near the Crime Scene

In this setting, illustrated in Fig. 4, the RISEN System is transported and installed at the crime scene. However, while the RISEN sensors are placed at the crime scene, the 3DA-CSI System remains in a vehicle, stationed near the crime site, thus delivering good processing and power capabilities.

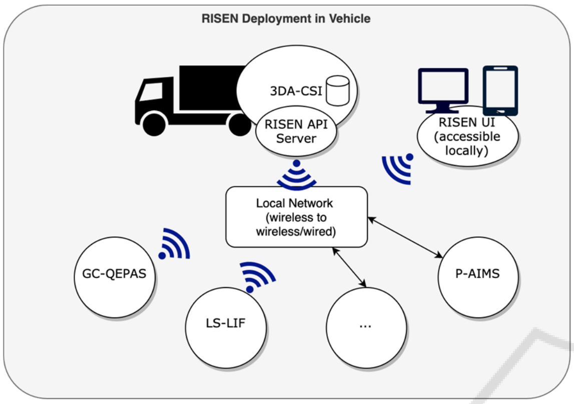

Figure 4: Deployment in Vehicle.

A local wireless network is established to connect all RISEN modules. Where needed, network repeaters are installed to ensure adequate network coverage. The RISEN sensors send measurements to the 3DA-CSI System. The investigator accesses the 3DA-CSI System at the crime site using a computer in the vehicle or, via a portable computer or App, at the crime scene. All information is locally stored in the 3DA-CSI System.

This setting is very similar to the previous one and presents as main advantage the increased computing and power capabilities provided by the infrastructure in the vehicle.

3.5.3 Cloud Deployment

This setting, illustrated in Fig. 5, is advantageous for situations where network connectivity with a central 3DA-CSI System is possible and desired. It also takes advantage of advanced computing capabilities provided by a stable infrastructure. However, it requires continuous network connectivity, a requirement that is not present in all crime scenes. Moreover, security concerns might arise concerning assurance of data confidentiality. The fact that the 3DA-CSI System is accessible over the Internet (even via a VPN) may bring additional security risks that might not be acceptable by law enforcement agencies (LEAs).

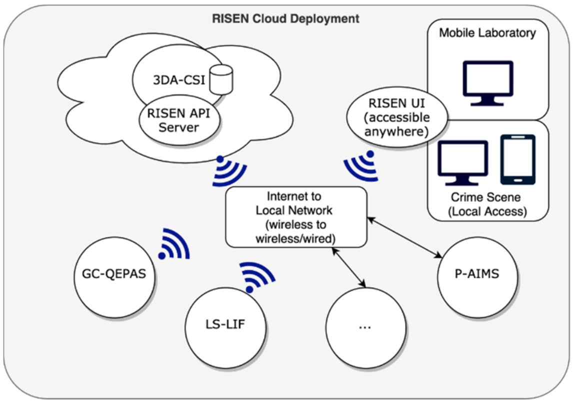

Figure 5: Cloud Deployment.

This setting is advantageous for situations where network connectivity with a central 3DA-CSI System is possible and desired. It also takes advantage of advanced computing capabilities provided by a stable infrastructure. However, it requires continuous network connectivity, a requirement that is not present in all crime scenes. Moreover, security concerns might arise concerning assurance of data confidentiality. The fact that the 3DA-CSI System is accessible over the Internet (even via a VPN) may bring additional security risks that might not be acceptable by the LEAs.

3.6 Preliminary Results

RISEN provides a suitable environment for creating and demonstrating the capabilities of a Sensor API capable to seamlessly connect various specialised sensors used for forensic investigations.

The Sensor API was first tested using the GC-QEPAS sensor developed by CREO. GC-QEPAS is the acronym of *Gas Chromatography Quartz Enhanced PhotoAcoustic Spectroscopy*, which is one of the several techniques of spectroscopy allowing unambiguous detection and identification of gases and vapours by means of the measurement of their absorption band/peaks. The GC-QEPAS sensor is primarily intended for protection of operators against health and safety hazards (mainly toxic vapours and chemical warfare agents (CWAs)) while entering the crime scene. Moreover, the sensor can be used to identify volatiles evaporating from liquid/solid traces present at the crime scene (Viola *et al.*, 2019).

The GC-QEPAS demonstrated the Sensor API capability to communicate over a secure connection (HTTP over TLS), authenticate the sensor (use sensor credentials to perform operations), register the sensor, and receive sensor measurements in different formats: detection list, measurement spectra and pictures. Examples of received GC-QEPAS sensor data are presented in Fig. 6, 7 and 8.

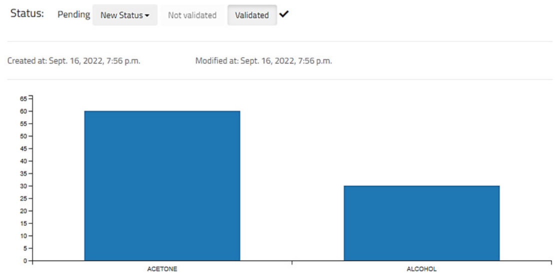

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Figure 6: GC-QEPAS detection list: ACETONE and ALCOHOL substances, including their probability.

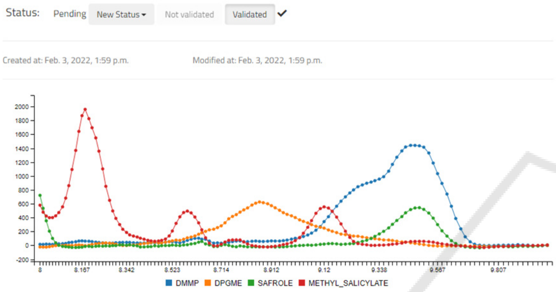

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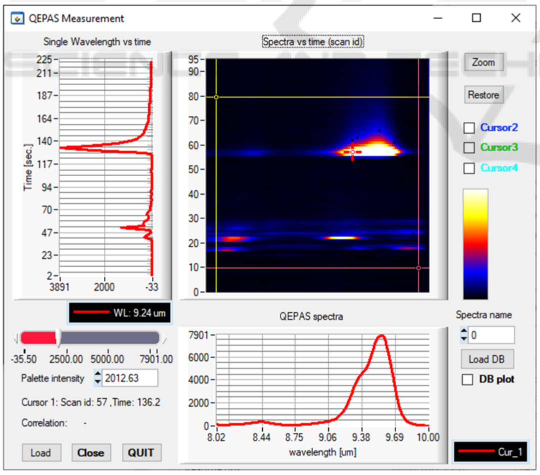
Figure 7: GC-QEPAS generated spectrum associated with different substances (DMMP, DPGME, SAFROLE and METHYL SALICYLATE).



Palette intensity 2012.63
Cursor 1: Scan id: 57 ,Time: 136.2
Correlation: -
Spectra name 0

Figure 8: GC-QEPAS sent picture related with a performed measurement.

4 STANDARDISATION

The RISEN project is developing a generic Sensor API that can be used by different RISEN sensors manufactured by different organisations. The Sensor API can be further generalised, allowing any CBRNe Sensor to connect and exchange information, in a network-enabled environment, with remote services in a uniform way.

Coordinated by DIN, a dedicated Committee for Standardization (CEN) Workshop Agreement (CWA) on *CBRNe SENSOR API - Network Protocols, Data Formats and Interfaces* (DIN, 2022) has been proposed with the following reasons in mind:

- Facilitate analyst data interpretation by using familiar, well-defined and consistent sensor data formats;
- Enable evidence management information systems to receive data from compliant CBRNe sensors without requiring custom developments;
- Include 3D-spatial support in sensor data, enabling 3D data location;
- Improve operational autonomy and efficiency with digitalisation of traces and evidences;
- Enable forensics data sharing between practitioners.

This proposed standard has relation with the following:

- ISO 21043:2018, Forensic Sciences parts 1 to 5 (ISO, 2018);
- ISO/IEC 30128, Information technology — Sensor networks — Generic Sensor Network Application Interface (ISO, 2014);
- ISO/IEC series 29182, Information technology — Sensor networks: Sensor Network Reference Architecture (SNRA) (ISO, 2013).

The CWA kick-off meeting was held on 10 October 2022, in Jurmala (Latvia), as part of the RISEN plenary meeting. This workshop is to be followed by additional four Workshop meetings and web conferences, allowing comments and suggestions to be submitted for supporting standardisation.

5 CONCLUSION

RISEN introduced an innovative concept in forensic investigations by developing and connecting a set of sensors for handling traces on site, thus optimising trace, detection, visualisation, identification and interpretation on site, with a consequent reduction of the time and resources consumed by laboratory analyses.

Resulting from a need to connect different sensors to a remote server, the concept of a modular network-enabled approach, was envisaged. This approach resulted in the RISEN Sensor API. With interoperability and scalability as key goals, the Sensor API was implemented considering open-source and widely used technologies, including the REST architecture, HTTP(s), TCP/IP, JSON and MQTT.

The Sensor API was tested subsequently, using the GC-QEPAS sensor, and successfully demonstrated the capability to register the sensor and receive its measurements in different formats. It was also validated the Sensor API's capability to be further generalised, thus allowing any CBRNe Sensor to connect and exchange information, in a network-enabled environment, with remote services in a uniform way.

Under the leadership of DIN, a CWA was promptly initiated to promote standardisation of the Sensor API. The new CWA aims to define the API for CBRNe sensors, enabling specialised IT system manufacturers to provide innovative solutions (beyond sensor scope) atop of well-known interfaces and data models. At the same time, CBRNe sensor manufacturers can focus on sensor development work, benefitting from already defined interfaces and data models. Finally, forensic investigator end-users can better understand and analyse (well defined) sensors outputs, thus improving their work efficiency and promoting technology acceptance.

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

REFERENCES

Champod C. (2013) *Overview and meaning of identification/individualization*. In: Siegel JA and Saukko PJ (eds) Encyclopedia of Forensic Sciences. Waltham: Academic Press, 303-309.

DIN (2022). *CEN Workshop on 'CBRNe SENSOR API Network Protocols, Data Formats and Interfaces'*. Online article. Published at: 2022-09-08. Available at: https://www.cencenelec.eu/news-and-events/news/2022/workshop/2022-09-08-sensor/

ISO. (2013) ISO/IEC 29182-1:2013. *Information technology — Sensor networks: Sensor Network Reference Architecture (SNRA) — Part 1: General overview and requirements. Edition 1.* Technical Committee: ISO/IEC JTC 1/SC 41 Internet of things and digital twin. Publication date: 2013-06.

ISO. (2014) ISO/IEC 30128:2014. *Information technology — Sensor networks — Generic Sensor Network Application Interface. Edition 1.* Technical Committee: ISO/IEC JTC 1/SC 41 Internet of things and digital twin. Publication date: 2014-11.

ISO. (2016) ISO/IEC 20922:2016. *Information technology — Message Queuing Telemetry Transport (MQTT) v3.1.1. Edition 1.* Technical Committee: ISO/IEC JTC 1 Information technology. Publication date: 2016-06.

ISO. (2018) ISO series 21043:2018. *Forensic sciences. Edition 1.* Technical Committee: ISO/TC 272 Forensic sciences. Publication date: 2018-08.

Margot, P. (2011) *Forensic science on trial - What is the law of the land?* Australian Journal of Forensic Sciences. 43:2-3, 89-103.

Manso, Marco; Chirico, Roberto; Peltola, Johannes; Engström, Philip; Larsson, Håkan; Berggren, Jimmy. (2020) *The RISEN Project – A Novel Concept for Real-time on-site Forensic Trace Qualification*. International Command and Control Research and Technology Symposium (ICCRTS). 25th ICCRTS Proceedings. https://doi.org/10.5281/zenodo.4264926

Viola, R., S. Mengali, N. Libetatore, S. Zampolli, I. Elmi and F. Mancarella. (2019) *Deployable Sensor for Trace Identification of Hazardous Chemicals in Dirty Environment, Based on FAST Gas-chromatography and Quartz Enhanced Photoacoustic Spectroscopy*. 2019 PhotonIcs & Electromagnetics Research Symposium – Spring (PIERS-Spring), Rome, Italy, 2019, pp. 223-228. (DOI:10.1109/PIERS-Spring46901.2019.9017698)