Accident & Emergency Informatics

Terminologies and Standards are needed for Digital Health in the Early Rescue Chain

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***Abstract*—Recently, the World Health Organization (WHO) has released a draft of its Global Strategy on Digital Health 2020-2024. Accident & emergency informatics (A&EI) addresses these targets providing fully automatic and specific rescue calls, which are generated by smart implants, smart clothes, smart wearables, smart vehicles, smart homes, or the Internet of Things (IoT). These smart environments monitor unobtrusively and continuously environmental, behavioural, physiological, or psychological parameters. In near future, they will autonomously generate specific alerts on adverse (health) events. A&EI interconnects the information and communication technology (ICT) systems in the early rescue chain. It enables semantically interoperable information exchange by the International Standard Accident Number (ISAN). In this paper, we describe key ICT components of the early rescue chain: alarming, responding, and curing instances. We suggest a minimum dataset that contains an event identifier, time and location, the type of event, and the number of victims including – if available – their identity. Concerning location, we address navigation on static as well as dynamic sites, within buildings, and brute-force getting into vehicles. Here, there is a lack of international classifications, terminologies, and standards to support semantically interoperable information exchange in the early rescue chain without any humans in the loop.**

Keywords*—Digital Health; Internet of Things, eCall, Minimum Dataset, International Standard Accident Number, System Interconnection, Data Exchange, Semantic Interoperability

I. Introduction

In September 2015, the General Assembly of the United Nations (UN) adopted a resolution on transforming our world: The 2030 Agenda for Sustainable Development [1]. Particularly, the sustainable development goal (SDG) 3 of this resolution is to ensure healthy lives and to promote well-being for all people of all ages. In May 2018, the Member States of the World Health Organization (WHO) adopted their 13th General Programme of Work (GPW 13) [2]. It has three interconnected strategic priorities to ensure healthy lives and well-being for all: (i) achieving universal health coverage, (ii) addressing health emergencies, and (iii) promoting healthier populations (Fig. 1).

WHO further identifies digital health as an opportunity to accelerate the progress for SDG 3, and to achieve the triple billion targets for 2023, as articulated in GPW 13 [3]. The WHO Global Strategy on Digital Health 2020-2024 addresses four targets, one of it is fostering cost-effective and efficient health systems [4].

Fig. 1: The WHO triple billion targets [2].

We believe that accident & emergency informatics (A&EI), i.e., digital health applied to the early rescue chain, empowered by international communication standards and unified terminologies provides methods and means for one billion more people better protected from health emergencies, and improved health coverage for a healthier population worldwide. This is in line with the latest WHO resolution on emergency care systems for universal health coverage: ensuring timely care for the acutely ill and injured [5].

II. Related Work

A. *Accident & Emergency Informatics (A&EI)*

We define A&EI as the science of systematically capturing medical data (e.g., symptom-based diagnostics, vital signs, and human behaviour) and environmental data (e.g., exposome [6], specific events), its integration concerning syntax and semantics, and its analytics in order to predict and avoid adverse health events, or to lower their impact to the individuals [7].

Therefore, the core mission of A&EI is saving lives by: (i) combining and jointly analysing medical and non-medical data, and (ii) involving all relevant decision-makers, actors, and stakeholders from politics, infrastructure and health management, and industry. Consequently, A&EI research focuses on the conception, implementation, and operation of sensor-enriched medical information systems.

B. Unobtrusive Health Monitoring

Unobtrusive health monitoring exemplifies such sensor-enriched medical information systems. Beside social relationships and spirituality, WHO defines

- Environmental (e.g., pollutants),
- Behavioural (e.g., mobility),
- Physiological (e.g., vital signs), and
- Psychological (e.g., anxiety, depression)

parameters that determine the WHO-defined quality of life (WHOQOL) [8]. Personal diagnostic spaces can monitor such parameters continuously, ubiquitously, and ambient, in particular in smart homes and smart cars [9,10].

C. Personal Health Records

Electronic health records (EHR) or personal health records (PHR) are in the scope of research for many years to collect medical information on specific individuals. Recent trends aim at providing mobile interfaces [11], but collected data still is incomplete and lacks interoperable exchange with other systems. Health Level 7 (HL7) Fast Healthcare Interoperability Resources (FHIR) or archetypes within the openEHR framework may provide methodologies for semantic interoperability with health data. However, scientists still focus on ontology, terminology, and data models when using FHIR in digital health [11].

D. Automated Alerting of Adverse Events

Adverse (health) events happen on all levels, at all ages, and in all nations. Automatic alerting of adverse events has not yet been established worldwide. However, some initiatives exist [12]. For instance, the European "eCall" system aims at bringing rapid assistance to motorists, who are involved in a collision anywhere in the European Union (EU). Effective since April 2018, the government made eCall mandatory in all new cars that are sold within the EU. However, while the car automatically initiates the emergency call and transfers a set of minimal data (SMD), then a human operator manually speaks to the vehicle occupants, makes the triage, and sends out the rescue team. Nevertheless, the authors estimate a 4% reduction in mortality if the alarm is faster, and the rescue centre receives geolocation data [12].

Another example is the 4th version of Apple's smart watch, that generates automatic SOS alerts if a fall is detected. In such a case, the watch displays a special note (Fig. 2). If the message remains not responded and further movement is not detected, the emergency call with GPS coordinates is made.

Fig. 2: Automatic SOS call from Apple Watch (source: https://support.apple.com/en-gb/HT208944).

E. Classification of Adverse Health Events

The International Classification of Diseases (ICD) in its 11th Revision has a dedicated chapter to describe injuries, their cause and extension codes that allow documenting a high level of detail for a mechanism of injury, cause, and environmental and social context [13]. ICD includes injuries resulting from acute exposure to or sudden lack of physical agents such as mechanical energy, heat, electricity, chemicals (e.g., oxygen), and ionizing radiation interacting with the body in amounts or at rates that exceed the threshold of human tolerance. ICD-11 also includes unintentional (i.e., accidental) causes of injuries. There are nine groups of categories, including transport injury event and fall as well as the residual classes 'other' and 'unspecified'. For transport injury events, the codes differ road traffic, land, railway, water and air transport. The extension codes (Chapter X) further specify the dimensions of injury and external causes. For instance, part and type of place can be specified with ICD-11 codes, such as "XE4XM" is determining the kitchen as a part of a building or grounds where the injury has happened.

ICD is designed for a range of de-facto use cases in the context of illness and death. However, ICD-11 does not include entities that could be used to describe the fastest way from a building entrance to the specific room, where the incident has occurred.

III. Methodology

A. Defining the Need

For smart clothes, smart wearables, smart cars, and smart homes, we need to substitute operator-based responding to emergency calls, as there might be no counterpart to answer the call centre-based operator's questions. Therefore, all required information must be passed across the systems automatically and semantically interoperable. Hence, digital health for the early rescue chain still needs appropriate terminologies and standards.

B. Analyzing the Systems Involved

When smart devices communicate accidents or emergencies, the following ICT systems are involved (Fig. 3):

- Alerting systems (e.g., smart home, smart car, or smart clothes),
- Responding systems (e.g., triage, disposition, rescue teams on street, air, water), and
- Curing systems (e.g., emergency room, stroke unit, hospital).

Fig. 3: Smart devices communicate adverse events.

C. *Structuring the Information Exchange*

In Germany, the memory aid for emergency phone-calls is the triple W: "Wo? Was? Wieviel?". Accordingly, accidents & emergencies require exchanging at least the following information:

- Where has it happened? (not only GPS coordinates, but the semantic location in terms of address, building part, floor plan, level, room),
- What has happened? (not only traffic accidents, but all health-related issues), and
- How many people injured? (not only the number, but further details for all involved individuals).

D. *Suggesting a Minimum Dataset (MDS)*

Concerning electronic communication in an emergency, we focus on the alerting and responding systems. Smart systems may environ several individuals, but as the environment (not the human) generates the alert, we suggest the event as the root of the MDS with information about:

- Event identifier
- Event time and location
- Event type
- Victims involved (by number and identifier, if available)

E. *Scalability*

Automatic information systems require a certain level of infrastructure. In a first approach, the information would be limited to notification of site. In further steps, body sensors and room maps would provide inside-building navigation and vital data that allow preparations a quick response. Accordingly, the data set could be expanded, for navigational or health-related information, as feasible in a particular setting.

IV. Result

A. *Event Identifier*

When we buy books, the International Standard Book Number (ISBN) is a valuable resource, since it provides a unique identifier disregarding different publishers or editions. Accordingly, the International Standard Accident Number (ISAN) aims at establishing a unique identifier for adverse events such as accidents and emergencies [14]. An ISAN token will establish secure communication between alerting, responding, and curing systems (Fig. 4). It is composed of

- Time (e.g., ISO 8601, RFC 5322) and time uncertainty,
- Location (e.g., global positioning system (GPS) coordinates, road maps) and location uncertainty,
- Elevation (e.g., indoor floor level, height above sea level, height above ground level) and elevation uncertainty, and
- Unique identifier (e.g., media access control (MAC) address, international mobile equipment identity (IMEI) number, random number).

Fig. 4: The ISAN can be QR-coded for automatic processing.

To support stakeholders implementing the ISAN, representational state transfer (REST) services are available at https://isan-service.plri.de/. Enriched with a graphical user interface (GUI), the web services implement the ISAN specification and facilitate working with ISANs. In particular, they can be used to [15]:

- generate a new ISAN from raw data,
- visualize a single ISAN for a human,
- convert an existing ISAN into the preferred format. and
- analyse if two ISANs may belong to the same accident.

B. *Event Location*

Neither street addresses nor GPS coordinates (as being part of the ISAN) are helpful for site navigation, where several buildings, smaller roads and pathways, or other components assemble a static setting, usually on private areal. In general, major accident sites may need further information for on-site navigation:

- *Static Sites*: Figure 5 exemplifies the complex building structure of the Hannover Medical School, Hannover, Germany, as one of the largest German university hospitals. Here, however, a campus map might present too much information, and a portable document format (PDF)-enveloped image cannot be understood automatically in terms of semantic operability. Therefore, we suggest to base navigation on directions, such as (i) straight forward, (ii) follow the road, (iii) keep left or right, and (iv) turn left or right; and counting the number of landmarks such as junctions or diversions. Also, distances may be given.

Fig. 5: Site Map of Hannover Medical School.

- *Dynamic Sites*: For vehicle pileups, the essential question for the first-arriving rescue team is where to start: which people need help first? In a future with car-to-car communication, that information might be determined automatically, and the rescue team needs guidance, accordingly. In contrast to site maps, the composition of cars and the path to move is dynamic, but computable by GPS coordinates of all involved objects. Navigation can be based by left- and right- or front- and back-side passing of individual vehicles (Fig. 6).

Fig. 6: Massive Vehicle Pileup (Virginia, USA, 12/22/2019).

- *Indoor Navigation*: When it comes to navigation within a building, we do not only have the directions: forward, left, and right, but also up and down for stairways and ramps. Instead of junctions, we count doors or windows as guiding landmarks (Fig. 7).

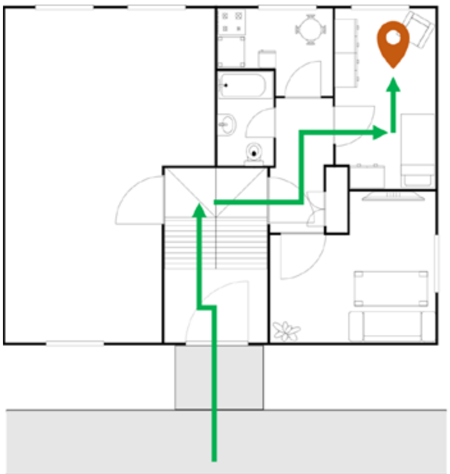

Fig. 7: Floor plan for indoor navigation.

- *Vehicle Rescue Sheets*: Another type of site maps are vehicle rescue sheets (Fig. 8). Modern cars have pyrotechnical airbags, larger batteries and other components that shall not be damaged if a brute force opening of the vehicle is required. A PDF-enveloped bitmap image cannot be processed automatically, and hence, a more comprehensive model for the vehicle-specific information is required.

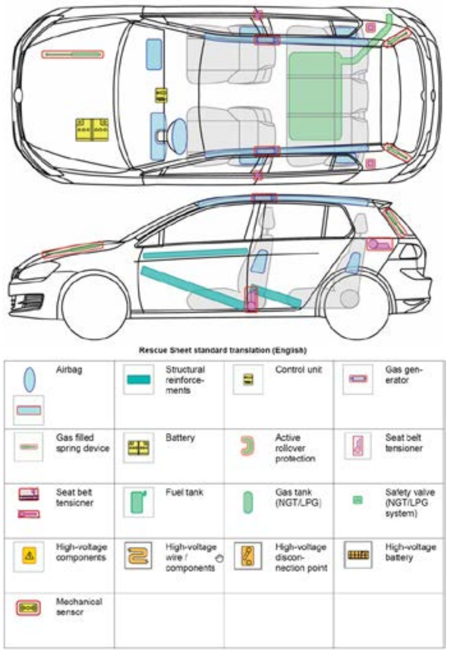

Fig. 8: Rescue sheet provided by the vehicle vendor.

C. Event Type

ICD-11 has all the elements to describe the type of event and any resulting injury. The underpinning technology allows easy integration with notification systems.

D. Victims involved

We suggest an MDS that includes not only the number of involved victims, but also – if available – their identification. Personal health numbers or social security numbers are not yet established uniquely and there is ongoing research on the master patient index (PMI) [16]. Using such unique identifiers will allow accessing the PHR of victims and providing essential information (e.g., allergies, vaccination) to the teams of the responding and curing instances.

According to the scalability of our concept, continuous vital sign monitoring of involved victims will be added at later stages, disregarding whether the measures are taken unobtrusively in smart homes or smart cars [17] or on the human body with smart clothes or smart wearables [18]. Here, standards for the coding of continuously delivered vitals are needed as well as a (temporary) subject identifier that is linked to the ISAN.

V. Discussion

Automated alerting of adverse events has not only high potentials in speeding up emergency support but also for injury prediction and prevention. According to Al-Shorbaji et al., building, linking, and analysing PHR in conjunction with establishing injury event and care registries can contribute substantially to healthier lives and safer transportation [19].

In our concept, we regard the adverse event as the root point to interconnect data from different sources. Hence, in a traffic accident with two vehicles, both will create an event with different ISANs, and these ISANs may link to multiple victims. At later stages, data analytics will provide relations between such ISAN-determined events, e.g., by comparing the MDSs.

In this paper, we have focused on the smart environments homes and vehicles, and analysed dynamic (vehicle pileup) and static (building ensemble) on site navigation as well as indoor navigation. Other sites such as mines, (nuclear) power plants, or tsunamis may need further terminologies and standards. Also, alarming devices might pass additional information on the accident (e.g., the height of a fall, the speed when crashing) which need semantic interoperable communication standards.

VI. Conclusion

Automated alerting of adverse events requires further terminologies and standards to interchange information between the ICT systems of the alerting, supporting, and curing instances that are involved in the early rescue chain. While ICD-11 already provides all elements to describe event types and injury, we still need standards for fast navigation towards the accident or emergency site as well as on such sites. In conclusion of this statement paper, terminologies and standards still are needed to support A&EI and digital health in the early rescue chain.

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