Technologies for first responders' landscape: how to create a successful acceptance and the road ahead

This white paper puts forward the vision of the H2020 RESCUER project (first RESponder-Centered support toolkit for operating in adverse and infrastrUcture-less EnviRonments, project ID 101021836, https://cordis.europa.eu/project/id/101021836, www.rescuerproject.eu), (July 2021 - June 2024), a Research and Innovation Action (RIA), aimed at addressing the challenges faced by first responders, both as an individual and as a team member in a hostile, infrastructure-less environment, under adverse conditions. The project developed a toolkit offering sense augmentation through enhanced sensorial input, precise and infrastructure-less self-positioning, cognitive support, and multi-sense augmented reality interfaces, improving their focus and capability to utilise information and robust ad hoc intra-team communications.

Background

First Responders (FRs) comprise a diverse group of individuals highly trained and committed to protect and save lives in the face of emergencies and disasters. Over the years, advancements in technology have significantly transformed the landscape of emergency response, empowering FRs with tools and capabilities that were once the realm of fiction. This transformation is driven by a dual objective: enhancing the effectiveness and safety of FRs while also augmenting their capabilities to surpass the limits of human strength and ability. The foundation of modern emergency response technology rests on a multidisciplinary approach, leveraging insights from fields such as information technology, engineering, materials science, and cognitive psychology. Operational protocols have been standardized to integrate technological innovations seamlessly into the workflows of FRs, ensuring optimal utilization and compatibility with existing practices.

One of the key drivers of technological advancement in emergency response is the recognition of capability gaps, ranging from real-time tracking to the provision of advanced protective equipment, which underscores the critical role of information technology in addressing the evolving needs of FRs. The quest to endow FRs with abilities enabling them to match the challenges they face in the field through technology has been a focal point of research and development endeavours. In this ambitious undertaking, the need to extend the sensory and cognitive capabilities of the FRs, enabling them to operate effectively in adverse and infrastructure-less environments emerges as a challenge for technology: enhancing the human senses, namely vision, audition, olfaction, and taction. The RESCUER H2020 project (hereinafter referred so as RESCUER) addressed this challenge by exploiting high-definition cameras, directional microphones, hazardous gas detectors, ultrawideband radar sensors and head-mounted displays to visualise sensor-generated data as means to augment FRs senses, situational awareness, as well as safety and security.

However, the transition from sensory augmentation to actionable intelligence necessitates robust processing and interpretation mechanisms. Miniature-sized GPU computers and advanced algorithms play a pivotal role in aggregating, analysing, and prioritizing sensory inputs, ensuring that FRs receive relevant information in real-time. At the same time, collaboration emerges as a fundamental aspect of modern emergency response, wherein groups of FRs engage in coordinated efforts to mitigate hazards and rescue victims. Seamless communication, facilitated by wireless and mobile protocols, underpins this collaborative endeavour, enabling FRs to exchange vital information and coordinate their actions effectively.

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As technology continues to evolve, the arsenal of tools and technologies available to FRs expands. The convergence of artificial intelligence, robotics, and sensor technologies holds promise for further innovations, enriching the capabilities of FRs and enhancing their ability to save lives. On the other hand, the introduction of these new technologies often encounters a myriad of difficulties and challenges when tested in the field of emergency response. While technological advancements hold the promise of enhance emergency response capabilities, the translation of theoretical concepts into functional solutions faces hurdles such as compatibility issues with existing infrastructure, user interface complexities, and operational constraints in real-world scenarios. Moreover, the dynamic and unpredictable nature of emergencies necessitates adaptable and resilient technology that can perform optimally under adverse conditions, adding another layer of complexity to the testing and implementation process. Bridging this gap requires a concerted effort to engage stakeholders from both the technological and operational realms, fostering collaboration and co-creation to ensure that new technologies meet the practical needs and expectations of those on the front lines of emergency response. This collaborative approach is essential for designing and deploying solutions that seamlessly integrate into existing workflows, enhance operational efficiency, and ultimately save lives in times of crisis.

Current limitations/lessons learnt

RESCUER has been a large and ambitious project during which participants have faced multiple challenges and opportunities for learning and improvement. The key lessons learnt, which will undoubtedly be useful for future similar projects, are summarised below in some broad categories.

Management and coordination

In terms of management procedures, two things became evident: a) that a thorough documentation of steps, processes, notes, minutes, and action points is necessary and can ease a task handover if necessary; b) communication within the consortium must be concise, clear and targeted. Recipients should have a need to know and specific points to act on, to avoid an abundance of unclear or irrelevant correspondence, in which it becomes easy to overlook the relevant and actionable items.

Standard hierarchy of task and work package leadership usually works well, although in a large and complex project such RESCUER, a strong and proactive involvement of the coordination team is also necessary at all times, to provide a common direction and ensure convergence and synergy of the different aspects of the project. However, the most important lesson learnt in terms of coordination was the need to include both research/technical partners and end-user representatives in the coordination team. Although an end-user representative was not foreseen in the proposal, RESCUER took the initiative to appoint one and including in the coordination team early on, resulting in much improved coordination, communication and understanding throughout the project. This is even particularly important due to the different backgrounds and experiences of technical partners and end-users in the project, which may constitute a communication barrier needing some effort and goodwill to break through.

In addition, the consortium found that the allocated travel budget, though significant, imposed severe constraints on realizing the project activities, including pilot planning, multiple pilots, field tests, training, attendance to conferences, technical meetings, and general assemblies. All those are vital parts of a FR focused project, and none should be forfeited. RESCUER frequently combined two or more purposes into a single event to minimize travel costs. Therefore, a more careful estimation of the travel budget should had been done during the proposal phase.

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Communication and understanding within the consortium

A key action towards effective communication within technical partners and end-users is the disambiguation of terms and semantics. Our experience shows that this must be done at the beginning of the project, assuring the active participation of all partners, with the aim of defining key concepts and principles within the scope of the project. Technical partners must clearly understand the needs and requirements of end-users while those, in turn, must be aware of technical capabilities and hardware constraints. Such discussion has been proved to be needed during the whole execution of the project, aiming to manage expectations, and helping steer the technical developments and the testing conditions towards a common, realistic point of convergence. RESCUER found that the participation of end-users in the early technical tests and the visit of technical partners to pilot sites long before the actual pilots, helped each group to increase their understanding of their partners needs and limitations. This led to updated user requirements as well as technical design choices. Activities such as "life my life" (a set of exercises representatives from non-first responders' partners needed to conduct mimicking the operational conditions and real situations the first responders are facing in their day-by-day interventions in real scenarios) clearly contribute to that objective.

Equipment and technology maturity

A common point of misunderstanding can revolve around the maturity of the technical tools used – both software and hardware. In a research project, technical partners often use hardware of low or medium maturity. Even off-the-shelf products, such as XR devices, will often be put to uses outside their design parameters. Similarly, when considering software, either developed by the consortium or acquired, adapted, and used, will often lack robustness. At the medium TRL levels such research projects target, this is expected, and the objective is to develop and evaluate new and emerging technologies. However, FRs require technical tools to have a minimum level of consistency and robustness to facilitate meaningful evaluation. This becomes even more complicated when multiple technical tools constitute a suite or an entire system. In those cases, the potential impact of a low TRL level of a particular hardware or software may have in the system increases. This situation can be even more complicated due to unforeseen interactions between different software tools running on the same hardware, which, despite harmonized communication protocols, can still lead to competing for resource usage, including computing resources such as CPU, GPU, besides network constraints, since the computing power should be carried by the first responder in the operation, and as well batteries impose an extra weight and size

To mitigate the above-mentioned, RESCUER used a two-step methodology to evaluate and validate the tools: as *individual* tools or stand-alone, focusing on technical performance and usability in specific conditions; and as an entire *system* by including all tools simultaneously, testing more complete scenarios and system integration. Both types are important, as they focus on several aspects, both on the technical side and the end-user side. The interesting lesson learnt here is that it may be convenient excluding both low-maturity hardware and software from the entire system tests, as they may affect the performance and stability of the entire system. On the other hand, it is beneficial to increase the effort on individual tool tests, which put aside integration and stability concerns in order to validate the usage of recent technology in specific conditions and tasks. Finally, in terms of a homogenized integration, a uniform set of system and hardware requirements (including operating systems, library versions, and specific computer and other hardware models) used by all technical developers is especially important to ensure interoperability and avoid unexpected problems when deploying tools during the exercises in field-trials and pilots.

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Pilot exercises

Pilot exercises in FR-centred research projects are complex and time-consuming events due to the needed planning, preparation, and flexibility to conduct them successfully and overcome setbacks. RESCUER found useful to have multiple pilot planning sessions consisting of at least three meetings together with a visit to the pilot site early in the project. Both end-users and technical partners must be involved in these activities, to reach a common understanding of the site and devising a relevant scenario. The main objective of a pilot is the validation of new technologies, and a detailed evaluation methodology should be in place first, shaping the planning of pilot exercise. Technical limitations must be taken into account, regarding the conditions the technologies are suitable for. As an example, battery life of many hardware components limited the duration of scenarios to a maximum of 45 minutes. Furthermore, the number of hardware devices available imposes a hard limit to concurrent users, and therefore, the total evaluations that are performed.

The above-mentioned problems increase when there are many software and hardware components, which will probably lead to some interoperability issues and bugs arising when they are all working together during a pilot exercise. Pausing tools development and holding remote testing sessions in the weeks before the pilot exercise is strongly recommended. Even so, non-expected problems will become apparent when the tools are in physical proximity and deployed on multiple devices. To ensure a smooth pilot exercise, time slots of significant length must be set aside for interoperability testing and on-the-fly fixes. Depending on the scope and phase of the project, two or three full days can enough to smooth out such problems.

Training has been another key point in successful pilot execution since the users cannot properly evaluate technologies if they are not trained and familiar with their use. A multi-pronged approach, consisting of user manuals, lectures, demonstrations of each tool, and hands-on training on the eve of the pilot is necessary and can drastically impact the pilot's execution. In addition, the regular involvement of a constant, core team of end-users, which are able to follow the technical developments and test them on multiple in-person meetings throughout the project can provide a well-trained team which is also perfectly position to train additional users that are not regularly involved.

Finally, regarding unexpected setbacks that may occur during a pilot exercise, some flexibility can serve to mitigate them, such as technical difficulties, hardware failures, or adverse weather. RESCUER used to address this problem by allocating two days for pilot testing. This provided a degree of security, as activities that were unsuccessful or impossible one day could be rescheduled for the next day at relatively short notice, while increasing the number of users who could test and evaluate the technologies.

Goodwill and common goals

Last but certainly not least, the goodwill of the whole consortium and the sharing of common goals may have a tremendous positive impact on all of the above and every aspect of project execution. RESCUER was blessed to have this, as in the three years of its duration partners have become true colleagues, understanding, supporting, and improving one another. All shared common goals: to evaluate how and which innovative technologies can improve FRs' efficiency and safety, how they fit into their training and procedures, and what can be adapted and improved in the future. RESCUER was a small but major step in this journey, only made possible by a unity of purpose between FRs and technical partners.

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Recommendations for similar RIA projects

Research innovations actions, particularly those integrating diverse stakeholders and pioneering technologies, necessitate adept project management and seamless coordination to achieve success. Drawing from insights acquired during RESCUER, the consortium is eager to disseminate key recommendations for effective project oversight and coordination within research undertakings.

From a management and coordination point of view, starting with the proposal phase, it is imperative to allocate a generous travel budget to encompass all requisite activities comprehensively, mitigating potential constraints on the project execution. This entails detailed calculation of travel-related expenses to forestall budgetary limitations from impeding progress.

Moreover, throughout the project implementation phase, thorough documentation of project milestones, procedures, and action items is essential. Comprehensive archiving of these details facilitates a seamless task transition and ensures continuity. Clear documentation fosters effective communication within the consortium, enhancing comprehension and alignment, and a clear definition of the expected results of the "integrated" systems and its performance achievements every month of the project, and for every pilot, allow to a better and smooth understanding and avoids the disappointment of testing personnel facing non-working features which were stated in the project Description of the Action or requested during the requirements phase

Concise and targeted communication within the consortium is paramount. Messages should be succinct, enabling recipients to grasp their roles and responsibilities unequivocally. A proactive coordination team should be actively engaged to provide cohesive direction and harmonize various project facets. Furthermore, the early involvement of end-users in all project processes, requirements, and decisions is imperative. Integrating end-user representatives into the coordination team from project inception enhances communication and ensures alignment with user needs.

Effective intra-consortium communication and understanding are pivotal, particularly in research endeavours geared toward FRs. Early clarification of key terms and concepts lays the groundwork for effective communication, fostering stakeholder engagement and managing expectations. Continuous dialogue throughout the project lifecycle ensures stakeholders remain informed and invested, facilitating collaboration and project success.

The early involvement of FRs in technical tests and pilot site visits promotes mutual understanding and collaboration. Iterative updates based on ongoing discussions ensure alignment with evolving stakeholder needs. Additionally, clarifying tool maturity levels early on and conducting thorough testing assesses performance and integration, thus enhancing system stability and interoperability.

To ensure successful pilot exercises, detailed planning but also flexibility is essential. Early planning sessions involving end-users and technical partners facilitate scenario development and mutual understanding. Establishing a clear evaluation methodology and conducting comprehensive interoperability tests minimize issues and setbacks. Comprehensive training and maintaining a core team of well-trained FRs are vital for successful outcomes.

In conclusion, conducting rehearsals or *"cold runs"* before pilot exercises is crucial to ensure that stakeholders are acquainted with their roles and responsibilities and providing insights into time requirements for activities during official pilot days. Technical partners should be informed of scenarios and cease tool development before final testing, thereby ensuring smooth technical integration and effective pilot execution.

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