The SHERPA project: smart collaboration between humans and ground-aerial robots for improving rescuing activities in alpine environments

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Abstract — The goal of the paper is to present the foreseen research activity of the European project "SHERPA" whose activities will start officially on February 1th 2013. The goal of SHERPA is to develop a mixed ground and aerial robotic platform to support search and rescue activities in a real-world hostile environment, like the alpine scenario that is specifically targeted in the project. Looking into the technological platform and the alpine rescuing scenario, we plan to address a number of research topics about cognition and control. What makes the project potentially very rich from a scientific viewpoint is the heterogeneity and the capabilities to be owned by the different actors of the SHERPA system: the human rescuer is the "busy genius", working in team with the ground vehicle, as the "intelligent donkey", and with the aerial platforms, i.e. the "trained wasps" and "patrolling hawks". Indeed, the research activity focuses on how the "busy genius" and the "SHERPA animals" interact and collaborate with each other, with their own features and capabilities, toward the achievement of a common goal.

Keywords: *Search and Rescue, Ground and Aerial Robotics, Cognitive Systems, Robust Control.*

I. Introduction

The goal of the paper is to present the main vision behind the European project SHERPA whose negotiation successfully concluded just at the time of the paper's submission and whose research activity will start on February 1th 2013. The real world scenario inspiring the SHERPA activities is the one of surveillance and rescuing in unfriendly and often hostile environments, like the ones in which civil protection, alpine rescuers and forest guards usually operate. In order to confine the research activity and the technological developments within reasonable boundaries, the project targets specifically the alpine rescuing scenario. It must be stressed, however, that the outcomes of SHERPA are applicable to wider rescuing and surveillance fields sharing with the alpine scenario many features and requirements. Some alternative scenarios pertaining the project are those of natural disasters in which civil protection usually operates, e.g. earthquakes, tsunamis, landslides, floods, in case of building crashes or in any operation in which large areas of territory, typically characterized by adverse terrain and weather conditions, must be efficiently patrolled while keeping costs and risks for human beings at reasonable levels. Within this context, the goal of SHERPA is to develop a robotic platform supporting the rescuers in their activity and by improving their ability to intervene promptly.

The numbers of rescuing in mountain regions, and in particular in the alpine area, are breathtaking. According to statistics provided by the Club Alpino Italiano ([1]), in 2010 about 6.000 persons were rescued in alpine accidents in Italy with more than 450 fatalities and about 30.000 rescuers involved, and with a worrying increasing trend of those numbers. In 2010 the Swiss Air Rescue ([2]) alone conducted 10.213 missions by helicopters in Switzerland with more than 2.200 people that were recovered in the mountains. Conveying those numbers to a global scale immediately gives the significance of the problem and the relevance of the real-world scenario.

Many features of the real-world scenario in which the rescuers and their technological support operate will influence the research activity of SHERPA, with special regard to the control and cognition abilities required to the team. The adverse environmental conditions in which the platform operates ask for robust automatic control and communication capabilities of the robotic platform. Furthermore, the presence of unstructured and dynamically changing environments makes the development of advance navigation capabilities an important issue, while the fact that the workspace is subject to relevant morphological changes asks for the development of superior cognitive abilities in terms of scene reconstruction. Finally,

the presence of a human rescuer will be deeply involved in accomplishing demanding tasks and thus not always available to supervise the robotic platform.

The SHERPA consortium involves 7 Universities (all represented in the authors list), 2 Small Medium Enterprises (SMEs) and one end-user (Club Alpino Italiano, [1]). The two SMEs (Bluebotics, [3], and Aslatech, [4]) are in charge of the design and construction of the ground rover and the rotary-wing aerial vehicles. The 7 Universities are responsible for a a mix of cognitive and control tasks. An international Advisory Board is also framed in the project.

II. The SHERPA Technological Platform and the "SHERPA Animals"

The activities of SHERPA are focused on a combined aerial and ground robotic platform suitable to support human operators in accomplishing surveillance and rescuing tasks in unfriendly and often hostile environments, like the alpine rescuing scenario specifically targeted by the project. The following actors compose the basic "SHERPA team":

- A human rescuer, who is an expert of the specific rescuing mission or surveillance activity (such as a mountain guide or a forest guard), is naturally a member of the rescue team. In the envisaged solution the human transmits wirelessly his position to the robotic platform and communicate with it using handy and easy-to-operate technological devices, which allow a natural interaction and do not distract the rescuer from his demanding actions. Vocal and gestural interactions are envisaged in SHERPA.
- Small scale rotary-wing Unmanned Aerial Vehicles (UAVs), equipped with small cameras and other sensors/receivers, are used to support the rescuing and surveillance mission by enlarging the patrolled area with respect to the area potentially "covered" by the human rescuer alone, both in terms of visual information and monitoring of emergency signals. Such vehicles can be technically designed to operate with a high degree of autonomy and be supervised by the human in a natural and simple way, as if they were "flying eyes" of the rescuer, helping him to comb the surrounding area. UAVs are specifically conceived to be safe, operable in the vicinity of human beings, and potentially deployable by the human rescuer by hand. As a consequence, they have limited autonomy, payload, and operative radius.
- A ground rover serves as a transportation module for the rescuer equipment, as a hardware station with computational and communication capabilities, and as a recovery and recharging module for the small-scale unmanned aerial vehicles introduced above. It is technically conceived to operate with a high degree of autonomy and long endurance, as well as to have a payload calibrated to carry relevant hardware. It is wirelessly connected to the rescuer, able to follow his movements, and to interact in a natural way. In order to improve the autonomous capabilities of the robotic platform, a multi-functional robotic arm is also installed on the rover, which will be useful especially in relation to the deployment of the small scale UAVs (both in terms of take-off and landing). The key elements carried by the rover are the computational and communication Hardware, the recovery/rechargeable station of the small scale UAVs and the equipment storage element. These are mechanically conceived to be confined in the "*SHERPA box*" that can be potentially decoupled from the ground rover and transported in another way, such as by means of the high-payload UAVs described in the following.
- Long endurance, high-altitude and high-payload aerial vehicles, with complementary features with respect to the small-scale UAVs introduced before, complete the SHERPA team. Within the team, they are used for constructing a 3D map of the rescuing area, as communication hub between the platforms in presence of critical terrain morphologies, for patrolling large areas not necessarily confined in the neighborhood of the rescuer, and, if needed, to carry the "SHERPA box" in places inaccessible by the rover. They fly at a height of around 50-100 m above ground (or trees). Two kinds of complementary technological platforms, already available and operating in the SHERPA research groups, will be considered: a fixed-wing UAV available at ETH Zurich and a rotary-wing UAV, the Yamaha Rmax, available at Linkoping University.

What makes the envisaged scenario interesting and potentially very rich from a scientific viewpoint, is the heterogeneity and the potential capabilities of the different actors of the SHERPA system that complement and enrich each other. Specifically, each actor can be better characterized in the following way:

- The human rescuer is potentially able to provide high-value inputs to the team due to his experience in the field and incomparable cognitive capabilities. On the other hand, the demanding rescuing activity and the hostile environment characterizing the targeted applications, make the rescuer presumably busy and focused on the task to be accomplished, and thus unable to lead and supervise the team continuously. The peculiarity of the real world scenario in which the human and the robotic platform operate affects the way in which they interact. The rescuer cannot be flooded with irrelevant information that might distract him from the ongoing task, and he is expected to provide inputs to the robotic platform in a natural way, through sketchy inputs to be properly interpreted by the robot. In this context, the rescuer plays the role of the "*busy genius*" of the team: he is very likely distracted by demanding rescuing activities and just able to provide sketchy, nevertheless valuable, inputs towards the achievement of the team goal.
- The ground rover serves as a carrying vehicle and docking station for the small-scale rotary-wing UAVs. It is characterized by remarkable autonomy, payload, and onboard

"intelligence", confined in the powerful computational hardware installed on the "SHERPA Box". On the other hand, it has intrinsic limits in terms of ability of reaching wild areas and overtaking big natural obstacles (such as rocks and trees) that are typically present in the considered real-world environment. It plays the role of the "*intelligent donkey*" of the team.

- The small-scale UAVs are characterized by limited autonomy and onboard intelligence (due to payload constraints) but with incomparable capabilities in terms of capturing data (like visual information) from privileged positions, high-manoeuvrability, hovering on hot targets, and following the rescuer in inaccessible (by ground) areas. Its radius of action is necessarily confined in the neighbourhood of the hosting ground rover due to the limited duration of the batteries. They play the role of "*trained wasps*" of the team.
- The fixed-wing and the Rmax rotary-wing UAVs are characterized by matchless eagle-eyed capabilities that allow it to patrol large areas with a limited amount of energy (in case of the fixed-wing configuration) and remarkable payload and ability to fly in critical weather conditions (in case of the Rmax rotary-wing vehicle). On the other side their configurations and safety issues force them to fly at high-altitude and far from obstacles and human beings. The "high-altitude" information captured by these vehicles enables optimization and coordination of the local activities of the team and complement the aerial capabilities of the small-scale rotary-wing whose operating radius is necessarily confined in the neighborhood of the rescuer. They play the role of "*patrolling hawks*" of the team.

Indeed, a collaborative interaction between the genius, the donkey and the wasps, with the "high-altitude" support of the hawks, can be envisaged by taking into account the specific roles and complementarity nature of the actors.

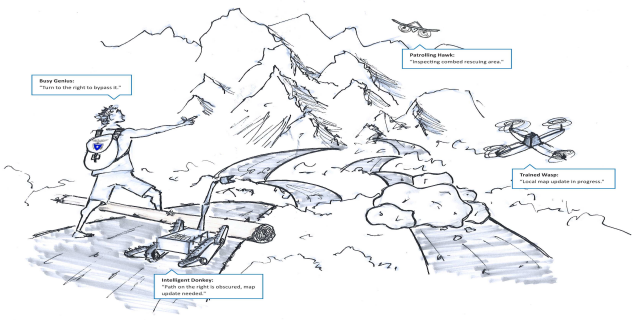

Fig. 1. A graphical sketch of the SHERPA team.

In the envisaged rescuing scenario, a swarm of many SHERPA teams might collaborate towards the achievement of a common task, like searching a missing person or patrolling a dangerous area, in order to improve the capabilities achieved by a single team. In the simplest "topology" the SHERPA teams operate "in parallel", with several human rescuers operating with the support of their-own ground rover and rotary-wing platforms, and with a single "high-altitude" fixed-wing aircraft supporting the activity of all the teams. In a further possible configuration, a single rescuer might supervise several robotic platforms helping him in patrolling a large area.

III. Project's solution concepts and approach

The main objective of the research activity is to equip the SHERPA team with cognition and control capabilities that are effective in supporting the rescuer in his mission. Practically, the technological platform is supposed to feed the rescuer with relevant information that can be decisive in the rescuing activity, such as detailed 3D maps of the rescue area, visual data and map of emergency signals in his neighborhood, suggested patrolling directions, evolution of rescuing mission and scenarios, such as retrieval of missing persons, risk of avalanches, change in the weather conditions, etc. Overall, the objective is to improve the perception capabilities of the human in accomplishing his task, by taking into account the demanding environment in which the mission usually takes place. In this respect, a crucial objective of the platform is to provide relevant and "filtered" information, without flooding the rescuer with irrelevant data that might distract his action. Remarkable cognitive capabilities in fusing, elaborating and filtering the multi-source information provided by heterogeneous SHERPA actors are thus a must. Instrumental in achieving this goal is the capability of the robotic platform to operate autonomously. The SHERPA platforms must be able to operate without the supervision of the rescuer (who might be deep in the search mission) in hostile environments like the ones typically characterizing an alpine rescue in which continuous communication and synchronization cannot be always guaranteed. In this framework the presence of the human and the way he is involved in the team is a distinguishing element of SHERPA. The envisioned interaction is not purely hierarchical, with the human supervising the platforms. Rather, collaborations with the "SHERPA animals" (i.e. the donkey, the wasps and the hawks) grounds on more elaborated strategies in which the human might be absent-minded as deep in his task, or present and willing to tele-operate the robots, or partially present and only able to provide sketchy, although high-value, inputs. This vision necessarily leads to a kind of heterarchical interaction, in which there is not a clearly defined "master-slave" relationship between the SHERPA agents, but rather distributed responsibilities among the agents that can eventually take their decisions autonomously and exchange information in a quite unstructured way (such as at irregular interval of time and with interaction initiated by any agent). In all the cases the interaction must be natural and effortless for the rescuer. Indeed, the fundamental question driving the cognitive and control research in SHERPA is: how can a "busy genius", an "intelligent donkey", "trained wasps" and "patrolling hawks" interact and collaborate each other, with their own features and capabilities, toward the achievement of a common goal?

IV. The Five SHERPA Benchmarks

In order to confine the research activity towards tasks that can be objectively evaluated and tested, five possible benchmarks will drive the SHERPA activities with a mix of "academic" and "industrial" significance. The benchmarks have been conceived in order to test all the individual features of the SHERPA actors, their own cognition and control capabilities, and their complementarities. Specific metrics to evaluate the performances of the robotic platform in the envisaged benchmarks will be developed in the project. The first two benchmarks, referred to as "Virtual Ground Leashing" and "Virtual Aerial Leashing", have been conceived in order to frame two possible "real world" situations having the interaction between the human and the platform (ground platform in the former case, and aerial platform in the latter benchmark) as the main focus. On the other hand, the third and the fourth benchmark, labelled as "Ground and Aerial Deployment" and "Team Coordination", are shaped in order to shed light on collaborative features of the SHERPA team, both at the level of intra-team for the first and inter-team for the second benchmark. Finally, the last benchmark, referred to as "The Avalanche", is conceived to be highly realistic, involving all the SHERPA actors and encompassing most of the platform functionalities tested in the other benchmarks. Demonstration activities will be associated to each benchmark. Regarding "The Avalanche" the test site of the *Institute for Snow and Avalanche Research* [5] will be used for the realistic demonstration of the final benchmark.

V. S&T Specific Objectives

The final technological SHERPA goal is the development and construction of the heterogeneous multi-robot platform described above supporting the human in accomplishing rescuing tasks in hostile environments. The development of the technological platform perfectly integrated with the human requires the attainment of a number of specific objectives that have been clustered in five subfields described below.

A. Enhancing Cognition through Multi-Modal Interfacing and Interaction

One objective of this project is the dynamic management and facilitation of distributed situational awareness structures and representations to support cognitively grounded decision-making. The project aims to study and develop interaction methods between the human and the platform that are less dependent on an emergency responder using traditional keyboards and visual displays. Interaction between the rescuer and selected SHERPA robots through gestures and speech are promising modalities for this purpose. In this respect the focus of project is not on the development of new HRI technologies but rather on the use of existing solutions to enhance human-robot interactions.

B. Decision Support Systems for Cognitive Decision Making and Cooperation

A major objective of this project is the development of appropriate functionalities to support both single-agent and multi-agent decision-making and their integration in the architectures described above. Decisions have to be made based on timely information and communication, and actions executed by both robotic platforms and humans alike in a timely and efficient manner in response to the plethora of contingencies that arise in complex emergency response situations like the ones characterizing SHERPA. Furthermore, a crucial objective of SHERPA is to make the team behaving as a whole and not as a collection of separate agents.

C. Single and Multi-Robotic Control, Actuation and Mechanical Design

A crucial objective is to design autonomous agents able to face the challenging alpine environment in which the rescue operations will take place. On one hand, this objective requires a specific mechanical design of the different aerial and ground agents so as to obtain a high level of robustness and integration of the complementary capabilities offered by each individual unit. On the other hand, a major role should be played by the availability of reactive planning and control policies able to deal with unexpected situations.

D. Distributed Architectures Supporting Cognition, Cooperation and Control

A further focus of the project is on architectural aspects motivated by the specificities of the SHERPA framework. Specific support for architectures at both the individual single platform level and at the multi-platform cooperative level is required on a continual basis at different levels of abstraction, ranging from real-time control and reaction to high-level deliberation. Control flow in both single-agent and multi-agent architectures is both horizontal (heterarchical) and vertical (hierarchical).

VI. Conclusions

The paper presented the foreseen research activity of the EU project SHERPA focused on the development of a mixed ground and aerial robotic platform supporting human beings in rescuing activities within hostile environments. The project targets specifically the alpine rescuing scenario and involves, as end-user, the Club Alpino Italiano ([1]). Although the project is focused on search&rescue in the alpine scenario, its S&T developments are reusable outside this particular application context. Besides the mechanical design of the robotic platform and integration of technologies, the main academic challenge of the project is the development of advanced cognitive and control capabilities that allow the platform to operate in the hostile environments typically characterizing Alpine scenarios (and others rescuing scenes) and to be perfectly integrated with the human rescuer.

References

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