Next Generation Human-Robot Telematic Teams*

Extended Abstract

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INTRODUCTION

The contribution investigates new methods and tools for design of next-generation telematic systems based on *hybrid teams of cooperating robots and humans*. The contribution presents selected issues of building the feature of *presence* in such telematic systems, deals with *human-robot integration* and *cooperation* issues together with drawbacks and benefits of the technology in question. The presented approach is focused onto investigation of a search and rescue type of tasks and provides evaluation of results obtained in proof-of-concept kind of experiments.

Keywords: telematic system, human-robot cooperation, personal navigation, search and rescue.

PROBLEM DESCRIPTION

Bidding to make the human activities easier and to become more powerful leads to focusing on development of specific technical tools for extension of human natural abilities. These cover mainly devices and tools that enable further improvements on the level of humans' sensory and perception system, providing him/her completely new, or normally unavailable, observations.

One of possible ways to achieve the previous goal is to apply so-called *wearable computing technologies* opening the possibilities to access desired information at any time and any place. So far, many daily working activities can endanger the human. To avoid this, (semi)autonomous machines - robots - can be used as substitutes for the living entities. Nevertheless, overtaking the danger from humans not always brings purely positive gain in the overall performance: the robot needs not to be capable of execution of the desired maneuvers or operations, or to obtain complete survey of the working environment.

Therefore, as ideal cut still remains a proper combination of the "classical" human approach to solve the given task being supported by a robot. Extension of human capabilities towards those, robots typically have, forms the topic investigated in this contribution and is shown in the Fig. 1.

In the case a human will be equipped by a communication [5] and sensing system [6], similar to ones robots rely on, selected robotic principles can also be applied to these humans (e.g. activity planning and/or optimization, human navigation and localization tasks, etc.). In particular, this means, the mechanical part of a standard robot is be substituted by a human body, and bringing his/her cognition into the problem solution. This step opens possibilities to build hybrid teams of cooperating humans and robots. Synergies in these teams belong to central advantages of this setup; complementary properties of diverse types of entities (robots and humans) result into substantial improvements in the final performance of the whole system. The major advantages of the support system in question can be seen mainly in specific applications, where classical perception schemes fail (or are substantially limited). These could be e.g. rescue mission in spaces with low visibility, or situations where local optimization is required with respect to global efficiency of the system.

Therefore, this contribution elaborates experiences with design and development hybrid human-robot telematic teams and related necessary technologies to verify the investigated principles in laboratory conditions in missions of a rescue type (Refer to: "Building Presence thru Localization for Hybrid Telematic Entities" project PeLoTe, [8]).

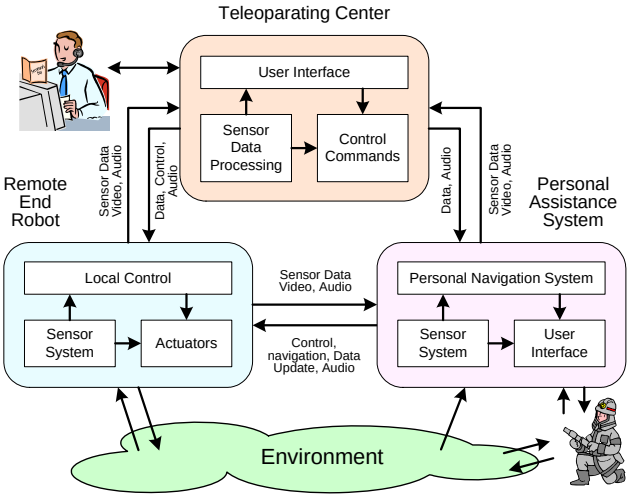

Fig. 1. Basic setup of a hybrid telematic system integrating (semi)autonomous robot and assisted human entity*

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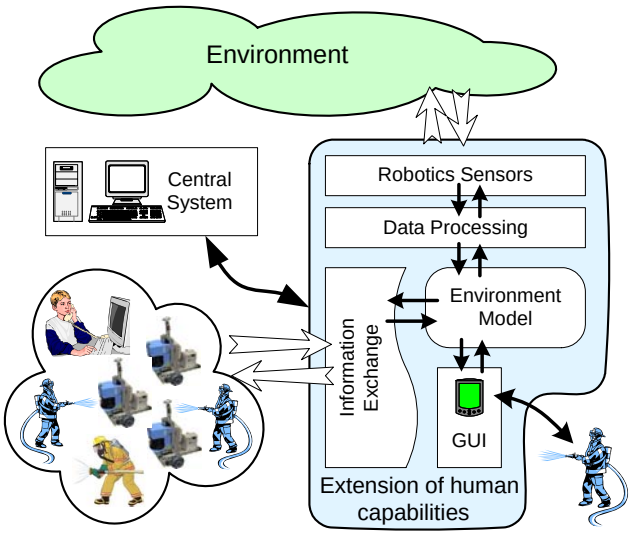

Fig. 2. Personal Assistance System (PAS) as support system for human sensing, communication and data sharing

III. Extension of Human Capabilities

One of the mentioned project targets has been design of a support system aimed at best possible extension of human perceptual abilities in the situations, where the human is expected to undertake decisions in stressing situations. This fits into the overall concept of integration diverse types of entities like humans and robots into an integrated team. Then, team existence allows setup of an efficient scheme for data exchange and sharing, all leading to team member cooperation.

While robots can perform their communication via native interfaces, the human desires a specific interface to participate in the communication traffic within the robot community. The interface shall allow him/her to establish a bidirectional communication in a form proper to the nature of the task solved and well adjusted to the human abilities. Such a Personal Assistance System (PAS), sketched in the Fig. 2, plays key role in the system design and definitely belongs to wearable technologies itself. The PAS system [6], [7] has been composed of multiple parts, all together targeted to improve human actors' perceptual capabilities and to establish communication with the other members of the community. The PAS system can also be understood like a multipurpose interface enabling the human to process sensor data, visualize system state information and to provide the human data of a robotic kind and origin in understandable form like maps, planned trajectories, etc.

From the users' point of view, the PAS system brings key functionalities in:

- processing, evaluation and visualization of sensor data
- indoor localization relative to the map and gives positions of other team members
- information sharing between other team members (human-to-human and robot-to-human)
- capability to influence/modify the environment map
- audio-visual and intuitive communication interface to the user,

all together contributing to mutual symbiosis of humans and robots in mixed communities.

IV. Target Usage

The mentioned system [8] was designed as a test-bed with emphasize on applications in search and rescue activities; the fire-fighting scenario has been chosen for demonstration of the project results, regardless the system can be applicable also to any similar inspection-like tasks [1]. Nevertheless, the theoretical background has been constituted with respect to applicability of used general principles for building such hybrid teams. The humans and robots as the complementary partners can effectively fulfill many kinds of tasks, moreover the extension of human capabilities open a new areas where can be utilized methods of robotics. Since it is possible to localize not only a robot but also a person in general environment (even in indoor with no infrastructure requirements) and disseminate it efficiently over the team, the overlying system for activity planning can find globally optimal solution for coordination of partial actions [4].

V. Experimental Results

The system has been implemented for experimental environments and tested in an extensive evaluation process. The testing process incorporated system performance measurements, evaluation of user's feeling, evaluation of within system interactions and considering the level of feeling presence as well as spatial awareness issues. Applied test tools were observations and questionnaires.

The mission tasks with critical parts simulated, but always executed in real environments (Fig. 5), were defined as:

- rescue of victims,
- extinguishing of fires,
- check of fire detectors,
- identification and avoidance of dangerous areas,
- exploration of the whole mission area.

To obstruct the execution of the test-case tasks, simulated features as low or zero visibility and unexpected occurrence of physical obstacles were introduced into the test environment. The subsequent evaluation of the systems' performance relied on:

Performance measurements:

- completion of tasks
- mission time
- questionnaire to judge own performance in the mission

Presence measurements:

- adapted version of the MEC Spatial Presence Questionnaire [3]
- memory test (a spatial awareness test)

Fig. 5. The system test-case experiment in a firebrigade-training facility.

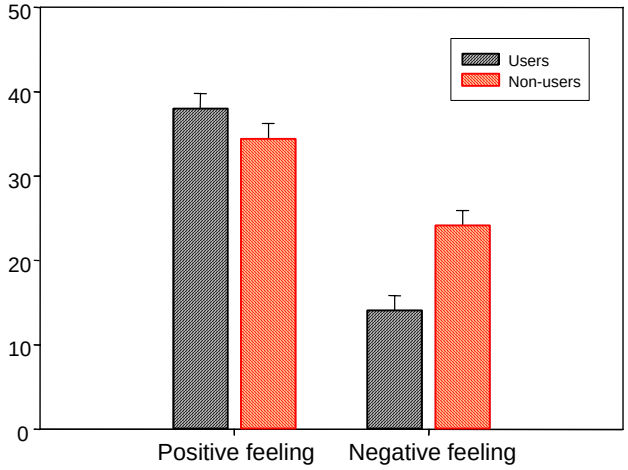

Fig. 6. Comparison of positive and negative feelings between the system user/non-user teams (PANAS).

User feelings evaluation:

- PANAS questionnaires [2]
- other questionnaires

Interaction of the users with the system:

- observations
- reasoning from diverse questionnaires

The system performance measures were evaluated in a comparative way, executing multiple mission runs of rescue teams with and without the system support.

Firstly, it has been identified, although the average mission time slightly increased for the teams with the system, these teams performed much better in qualitative aspect. The improvements were identified in better task fulfillments. Moreover, the PANAS evaluation of positive and negative feelings during the mission (Fig. 6) for system users/nonusers was unambiguously towards positive for the system users due to ensuring less stressing execution of the task.

The system user teams achieved absolutely highest coverage of the mission area. Furthermore, about 5% percent of the mission space was reachable exclusively by the robots, not accessible for the human actors. External observations has also shown that the teams relying on the system were able create and follow much better organized plans of their mission activity, that those without.

On the other hand, the teams having not the system support available were not able to achieve precise execution of the given tasks but were operating faster, and even displaying more nervous kind of behavior.

VI. Conclusion

The presented system can be considered as an experimental platform for verification of theoretical foundations with expected reuse in advanced buildups of heterogeneous human-robot communities. The within system acting humans and robots are able to effectively share knowledge and data, mutually communicate within the community in order to fulfill common shared tasks. In addition, the humans acquire new capabilities to act as a robot from a certain point of view, while they, as an integral part of robotic system, can receive, gather and disseminate different-natured data among all the community.

The system was designed with respect to increase a feeling of presence in semi-virtual working environment. The performed experiments successfully proved that the mentioned system brings various advantages in an idealized search and rescue mission. The system was evaluated by test users with different level of skills, ranging from professionals to beginners, in the field of search and rescue missions. Despite of the PeLoTe system is still in phase of the prototyped solution and doesn't provide full possible user comfort, it has been reviewed positively for its' performance not only by non-professional users but also by the fire-fighter community.

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