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NATO Research Study Group on Operator-Robot Interaction

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Abstract

Panel 8 on the Defence Applications of Human & BioMedical Sciences, a part of the NATO Defence Research Group proposed a Research Study Group (RSG) on telerobotic systems in 1988. Terms of Reference (TOR) for the group were developed by an Exploratory Group. Upon approval of the TOR by Panel 8, the RSG-18 on Operator-Robot Interaction (ORI) was formed with membership from Canada, France, Germany, the Netherlands, U.K., US Air Force, US Army, and US Navy. Belgium joined later and US Navy dropped off. The RSG-18 held seven semi-yearly meetings to consider ORI issues affecting effectiveness of telerobotic systems. A workshop involving invited experts was organized and held to obtain additional input to the topic. The main operational applications were identified by a subgroup of military users. The other subgroups considered function allocation between man and robotic subsystems, driving and emplacing a robotic platform using a high bandwidth video/control link, driving and emplacing a remote platform using a low bandwidth video/control link, and mission module man-machine interface. Some details of the workshop, its results, as well as conclusions and recommendations resulting from the RSG-18 are presented. A complete report on the work of the RSG-18 will be published as a NATO DRG report.

Introduction

The NATO Defence Research Group is responsible for promoting co-operation in research and technology which might lead, in the long term, to future equipment. One of the main objectives of the Group is to review and advise on the possible military consequences of advances in the fields of science and technology. The Group can undertake research studies on its own initiative or at the request of other NATO Groups and can identify and promote suitable areas for bilateral or multilateral co-operation in defence research and technology. The Group is also the only NATO body which sponsors Research Study groups (RSGs).

The oversight of specific topics, however, has been delegated to Panels as subordinate bodies. There are a number of Panels, most of them are fairly specific either to a field of science, e.g. optics or to applications area, e.g. air defence. Panel 8 on Human and BioMedical Sciences has probably the widest scope.

Exploratory Group (EG)

In 1986, Panel 8 received a proposal from Germany for a new activity on "Soldier-Robot Interaction". The Panel agreed that the topic was interesting and invited Germany to prepare a more detailed proposal and the interested nations to designate points-of-contact.

The next year Panel 8 established an Exploratory Group (EG) for the theme. Germany was the pilot nation for the EG. Canada, France, Netherlands, United Kingdom, and the United States joined the EG. Panel 8 directed the EG to produce a program of work, narrative rationale and the terms of reference (TOR) for an RSG titled Operator-Robot Interaction (ORI).

The EG reported to Panel 8 late in 1988 that an initial exchange of information took place among the interested nations and that further cooperation was desirable since many nations were considering the development of telerobotic systems (TRS). The EG recommended that an RSG be established to identify and prioritize critical unresolved ORI issues.

Consideration of TRS for military applications took place against the background of the following assumptions. TRS operating in unstructured environments will not be fully autonomous for quite some time. They will depend upon a close cooperation with the human operator who will define, control and monitor missions, and select the appropriate degrees of autonomy for each mission. The operator will decide when to start the mission and judge whether it was a success.

The potential military advantages of such systems were considered to include:

(a) Increasing operator effectiveness and survivability by removing operators from increasingly lethal or hazardous environments;

(b) Multiplying effectiveness with fewer personnel and the option of controlling multiple devices from a single control station.

(c) Providing long-term capabilities in sustained operations.

The TOR for the recommended RSG stipulated that the principal objective of the RSG was to establish an active exchange of information among member nations and to stimulate the military application of human-compatible telerobotic systems. The RSG was to identify the present state of knowledge, future trends, and unresolved problems area in TRS, and identify and analyze critical unresolved ORI issues.

Figure 1 shows a general schematic of a telerobotic system, including the interface between the human operator and the robotic system. The interface must be compatible with the overall requirements of system and therefore it needs to satisfy the functionality and capability requirements imposed or expected for the overall system.

The operator-robot interaction (ORI) issues are largely connected with the interfaces but are also strongly shaped by the overall system. They include the human factors matters of the design of displays, controls and the work environment. Other factors affecting the issues originate both from the human side (such as e.g. fatigue, physiological measures) and the robotic side (such as e.g., control allocation, world model).

Activities of the RSG

Panel 8 directed in 1989 that a new RSG-18 proceed with its work. The RSG membership was the same as that of the preceding EG. Belgium joined the RSG at its fifth meeting in May 1992.

Meetings of the RSG were held at semi-annual intervals from the spring of 1990 to 1993 and rotated between sites of the member nations. These meetings included visits to laboratories where robotics research and related activities take place. This aspect together with the program of presentations of national interests in robotics in general and specifically on ORI issues, provided an excellent opportunity for familiarization with the current work in the member nations.

The RSG drafted a program of work based on the direction that the primary objective was to identify unresolved ORI issues. In order to identify the applicable domain of the subject matter, some members of the RSG developed taxonomies of robotic systems in their nations and presented them to the RSG. Surveys of national ORI research were developed and presented by the members; the USA status quo was presented for each: Army, Air Force and Navy. Identified issues were assembled into a so-called "microstructure list" which addressed the modes and aspects of information feedback to operator, operator output, and system issues, such as e.g., latency latency, level of autonomy, etc. Thereby, it was

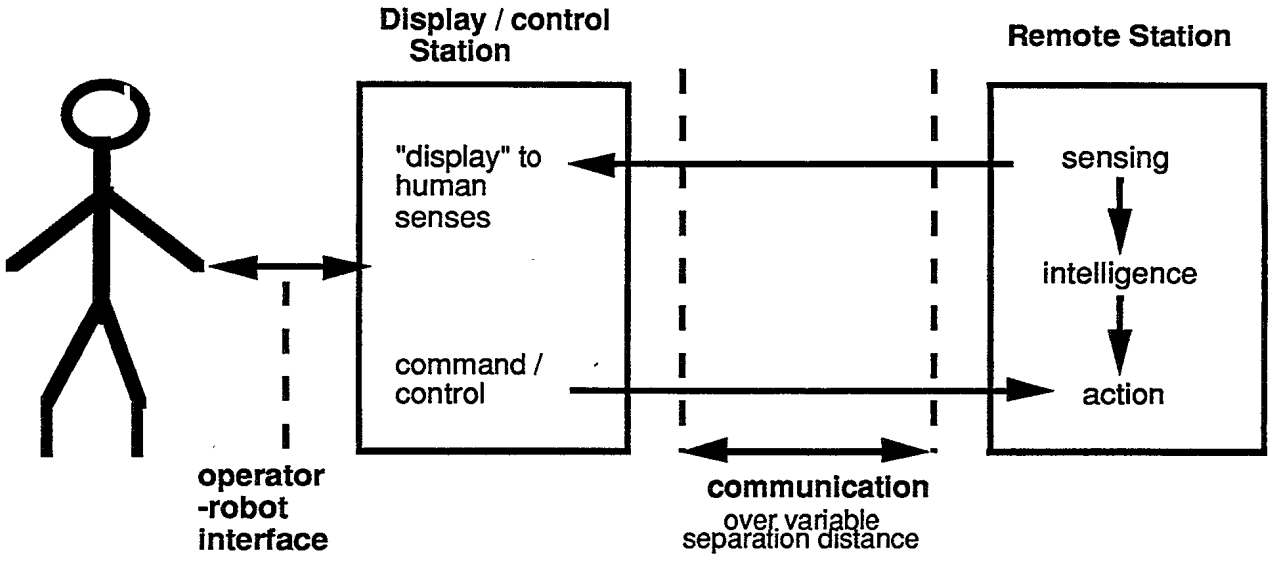

Figure 1. Outline of a telerobotic system including the operator-robot interface (ORI).

was recognized that ORI issues involve not only the controls, displays, and workspaces but also matters of functionality and capability of the telerobotic control systems as they interact with the human operator and his capabilities and limitations. Core ORI issues also evolved from integration of issues in specific cases into generic themes, such as e.g.: information transfer (to the operator) or restricted sensing (of the remote platform), etc. It was observed that the core issues, however, are modulated by the mission type: placement of a TRS (which involves travel to an operation site) or execution of a task involving mission module control activities conducted at a remote operations site. Obviously, the core issues are intertwined with the full range of the ORI issues listed in the "microstructure list". A complete list of the core issues, the "microstructure list", etc., will appear in the NATO DRG report on the work of the RSG-18.

In order to identify and prioritize unresolved ORI issues for constructive international collaboration, it was considered essential to constrain the topic. It was therefore concluded that:

- a clear military perspective of TRS applications should be developed,
- a common outlook between the users of the participating members should be established, and
- on such a foundation, the outstanding ORI issues could be identified for the common outlook.

These objectives, however, waere impossible to achieve directly within the RSG for a few reasons; one of them was that RSGs do not normally involve military users. Also, RSGs have no budget of their own or other resources for resolution of such a complex issue. However, a practical method to achieve a resolution of the objective was available in form of a workshop. Within the RSG-18, the idea of a workshop was first discussed during the Toronto meeting in the fall of 1990. This concept evolved and a Workshop on Critical Issues in ORI was organized.

Workshop on Critical ORI Issues

France organized and hosted the Workshop on Critical ORI Issues in Bordeaux in October 1992. The Workshop involved experts from the operational user community, experts from the technical development community, and scientists from the community conducting applied research on human factors of "unmanned" systems. Attendance was limited to about 50 invited participants. The seven NATO nations with membership in the RSG-18 were represented at the Workshop.

Five subgroups (SG) were formed to conduct detailed discussions on specific technical-operational ORI issues. The SG themes were as follows:

- SG-1 operational validation
- SG-2 planning, navigation and function allocation
- SG-3 Vehicle MMI (High bandwidth)
- SG-4 Vehicle MMI (Low Bandwidth)
- SG-5 Mission Module MMI (High and Low Bandwidth)

(MMI= Man-Machine Interface)

Participants were assigned to one of the SG, prior to the Workshop, with the aim to:

- produce SGs with approximately equal membership, and
- match as closely as possible the expertise of the delegates with the theme of the assigned SG.

The Canadian representation was limited to four invitees. They included:
SG-1: LCol J.G. Lindsay, DLAEEM 4,
SG-2; Mr. R.H. Chesney, Defence Scientist, Defence Research Establ. Suffield,
SG-3: Prof. P. Milgram, Head, Ergonomics and Telerobotics Control (etc) Lab., University of Toronto;
SG-5: Dr. J.J. Grodski, Head, Telerobotics, DCIEM.

The Workshop involved opening and concluding plenary sessions and SG working sessions. All invitees presented short position papers to a full assembly at the opening. The Workshop considered ORI issues in all three areas of operational environment for application of unmanned vehicles: land - Unmanned Ground Vehicle (UGV), air - Unmanned Air Vehicle (UAV), and sea - Unmanned Underwater Vehicles (UUV).

The SGs were expected to produce the following outcomes:

- SG 1 was expected to suggest a list of priority mission scenarios and a strategy for robotic operations and optimal performance assessment.
- SG 2 was expected to identify current limitations on robotic deployment due to technology or inadequate prior data, and areas in which intermediate and high level ORI research is required.
- SG 3 was expected to conclude on the priority design features of a high bandwidth teleoperated driving station and to establish which of those elements require further research.
- SG-4 was expected to indicate whether low bandwidth teleoperation is a feasible operating mode, and in what circumstances it may be used. They should identify those areas of ORI research that need to be addressed for optimal use of low bandwidth information.

- SG-5 was expected to list the technology requirements for remote operations, list the current shortcomings, and recommend the thrusts for future technical and ORI research required to overcome those shortcomings in the next 3 to 5 years .

The SG1 identified and recommended to the other SGs that their considerations be based on three highest priority applications of unmanned systems:

- unmanned ground vehicle for reconnaissance, surveillance and target acquisition (RSTA) missions;
- unmanned aerial vehicle for RSTA missions;
- telerobotic mine/ordnance detection, emplacement and/or disposal.

The detailed conclusions of the SGs are too lengthy to quote and they will appear in time as a NATO publication. In general terms, however, it can be stated that the Workshop identified the highest priority ORI topics, and provided a range of primary conclusions and recommendations.

The major themes of the priority ORI topics include:

- simulation with man in the loop
- interoperability
- pre communication and pre display data processing
- mission and automation level relevant displays
- mission and automation level relevant control
- workstation design
- performance analysis methodologies.

Some of the more general findings generated by the Workshop include the following:

- Robotics is an emerging technology that offers many potential benefits to the NATO military user community. Key benefits are removing personnel from especially hazardous duties, and multiplying the effectiveness of dwindling military forces.

- Integration of robotics platforms, systems and mission modules into the military will require an iterative process of prototype development (strongly based on operational requirements), field testing, and incremental improvement, along with modification of existing battlefield tactics and doctrine to accommodate this new technology.

- Specifications, evaluation schemes and norms must be developed for military robotics systems. This is an area in which considerable opportunity exists for international cooperation and shared research.

- Commonality of controls and display configurations and design would go a long way toward helping the operators of the different systems to share information and perhaps mission tasks (both planning and execution).

- The role of the operator will change significantly from that of a remote, full time in-the-loop controller to that of a supervisor of one or more remote systems or platforms as robotics systems become increasingly autonomous. Research in the area of mental and physical workload assessment will be required to provide information critical to task analysis and allocation of functions between the operator and the robotics system, but the level of understanding and the associated models of mental workload are still at a relatively primitive stage. Much work needs to be done in this area.

Post-Workshop RSG Activity

The RSG-18 met after the Workshop. It assembled the Workshop results and considered the R&D implications of the Workshop. The RSG identified a number of potential research topics with the capability for multi-national involvement. Most of these topics are of potential interest to the Canadian R&D effort and they include: sensor data fusion, enhanced depth displays, video overlay displays, performance analysis methodologies, predictor displays, augmented reality displays, obstacle avoidance, mission module/sensor control. It is important that a majority of these themes are domain independent, i.e. they may have a potential applications in either land, air, or sea environments.

The life of the RSG-18 ended with its seventh meeting earlier this year. In view of the significant outstanding issues identified in this area and numerous common interest topics in this domain, RSG-18 is recommending to its parent body, Panel 8 that the work ought to be continued. Specific recommendation calls for establishment of a suitable RSG. There is also a high probability of even broader involvement of NATO members in such a pursuit.

Conclusion

The necessity to obtain value for money in defence procurement is a common goal for many NATO countries, including Canada. For an emergent topic, such as teleoperated systems, there is real potential to achieve this through the sharing of national expertise without the associated limitations of applicability that arise in more mature fields.

Canada has a significant potential to contribute to multinational efforts in this area and more importantly, it can significantly benefit from such engagements. It is therefore important that a continuity of the involvement is maintained and supported.

Acknowledgments

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