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and training of new behaviors. Specific support and coaching will be required to enable this; simply providing a user with hardware will not be sufficient to implement robots in teamwork applications requiring either human-robot interaction as well as organization-robot interaction.

In addition to the two conscripts, an officer was also trained in robot operation, simply because officers are accustomed to master all the skills of the soldiers. Having an officer trained denoted knowledge on a high level about the robot system's capacities during tactical planning and briefing. The trained captain was second company commander and, thereby, a key person in the company.

The participants in military maneuvers are constantly graded, and leaders who attempt to deploy new features, instead of using traditional methods, take an increased risk of failure. Establishing a tolerant, supportive, and rewarding atmosphere during future tests will increase the rate of deployment.

5.3. When to Test

Performing the tests in a relevant environment is of major importance. In this case the most realistic settings available were the large-scale maneuvers performed during soldier training. It should, however, be kept in mind that training maneuvers differ from real missions regarding mission profile and risk willingness.

A qualitative approach seems to be the best option while testing in a large and complex setting such as one where several hundred persons act individually and dynamically on a mutual task. Quantitative measures are hard to apply as the course of events cannot be controlled and as the sought occasion might not occur often enough to be valued by statistics, but rather have to be regarded through the opinion of experienced participants. Further, it is not possible to perform repeated trials in the same test environment with a single test unit because of the learning effect.

Regardless of what methodology is applied during the phases of research and development, most of the army's evaluation is done through *participatory observation*, i.e., an embedded researcher (the officers and soldiers) uses the tested gear on a daily basis and forms a personal subjective opinion. Hence, even if qualitative approaches might not be the most scientifically distinct, they correspond to how fielded products will be regarded by the end users.

In order to provide well-founded viewpoints it is crucial for the test-user to have some level of hardware knowledge as a base for reasoning. An important quality of long-term testing is the decrease of bias connected to the introduction of a new product. It also gives the test group time to modify their behaviors to the new circumstances and to develop a mature opinion. In the beginning of the test period, the views on the system's capabilities and possible applications differed vastly between users. The initial interviews with the two officers produced numerous suggestions of how the robot might be used in urban warfare. Most of these proved unfeasible during later trials. Similarly, the unstructured interviews made during the trial illustrated that many of the suggestions of how to deploy robots were unrealistic. Not until the end of the deployment phase, when the final interviews were conducted, were the users experienced enough to reflect over robot deployment with more unity.

The more developed the introduced system is, the more relevant are the rendered results likely to be; in conflict there is a need to perform testing in early stages of the product design. An early introduction also enables parallel development of the system and the tactics for use. If this includes changing well-established doctrines this process might require significant time. When considering when to perform user testing it also has to be regarded that the users incorporated in studies will inevitably form an opinion about the tested system. Unsuccessful trials might have an overall negative impact, which can be very hard to recover from; hence, the point of time when to perform testing is a strategic compromise. The Packbot Scout was found capable enough to serve as a basis for research concerning search for objects, exploration, mapping, and payload delivery. Issues regarding mobility, endurance, robustness, radio range, user interaction, tactics, organization, and ethics concerning arming robots could be successfully investigated. Upon request, the users had the ability to see past properties that restrained the system, for example, the bulky operator laptop. On the other hand, implementation of the Packbot did not give the users the ability to discuss topics like autonomy or sensor data fusion with the same level of accuracy. Nor did the end-users have enough background knowledge to value the system in economical terms. On the other hand, it seemed more natural for them to value the benefits of the robot in comparison to other equipment.

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The project gave an opportunity to gain insights about the physical and mental recourses available amongst the users. It also proved to build a cooperation framework between the participating organizations and to serve as a suitable way to initiate the use of robotics in the addressed fields. Man-portable platforms were a suitable first step in the introduction of robots amongst the military. Dealing with larger platforms, potentially with autonomous functionality, will increase the demands for testing by orders of magnitudes due to safety regards, legislation, and practical issues such as transport, towing, fueling, training, and field repairs.

After the two years of trials, the officers of the company expect the robot activity to continue in order to keep the gained experiences up to date. Not proceeding might be regarded as negative by the personnel after their having identified robots as a tool with high potential.

5.4. Collecting Data

Manuals and instruction videos allowed access to basic users work procedures and terminology. As might be the case for many vocations, the documentation mainly covered the basics. Observation and participation were important means for gaining a holistic view of the users' work practice. Attending the briefings proved valuable to grasp the course of maneuvers. The opportunities for participatory observation proved to be very valuable for insights on the individual soldier's situation, as well as for establishing an informal setting for discussions.

The monitoring of a group as large as a company brought about a number of practical issues. The target of observation had to be constantly shifted in order to catch the overall situation. The frequent shifts together with the movements of the units in turn caused logistical demands such as bringing clothing, safety gear, supplies, and batteries for one or several days; arranging transport along with the combat vehicle convoys; and managing accommodation.

Circumstances during field studies made documentation difficult. Photography proved to be the most valuable out of note-taking, photography, and video. Taking notes in the field often proved unpractical while video imposed too high workload compared to the information gathered.

The unstructured interviews conducted during the maneuvers were important in getting to know the users and their activities. The short moments of conversations in the field, however, did not allow for reflections. The ten interviews at the end of the project served both as a recollection of the performed missions, and as a survey of the opinions about the system. Follow-up questions were used to verify the validity of the responses, which made it possible to evaluate in which areas the users had a well-grounded opinion. The respondents showed a high level of cooperation and willingness to share knowledge. Using an interviewer who had not participated in the field study decreased the risk of bias. The interviewer's little previous knowledge did not seem to cause friction with the respondents, but resulted instead in more detailed and descriptive responses, which opened the possibility for additional discoveries.

The questionnaire aimed to document the performed robot missions as well as to investigate the questions from the final interviews on a higher number of respondents. The questionnaire and the ten interviews were designed and performed in parallel. Both the final interviews and the questionnaire indicated which topics the users could answer with validity. A pilot-test of the questionnaire would have revealed this and enabled a more feasible survey design.

5.5. Delimitation and Outlook

The approach to have the end users deploy the tested product in a realistic setting limited the scope to technology that could be operated by privates and also have a fair chance to hold out in harsh environments. The authors' aims to motivate continued use of robots has favored applications that could show immediate success over applications which require more extensive reformation, even though the latter might have had a greater long-term potential. Increased radio range, new payloads, improved user interfaces, and tactical developments certainly hold potential for future progress; however, this article has not focused on speculations about technical improvements to come. The findings from current technology, though, are promising enough to justify implementation for a number of reasons. The Packbot Scout as a tool for MOUT imposes an acceptable load on the troops, while offering advantages for current uses. Even if the applications might not be the most commonly used in international missions, the benefits reaped from the Packbot proved signifi-

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cant enough to justify its presence in the toolkit for urban operations. Regarding possible future applications, a premature implementation of the robot would allow for tactical adaptations parallel to future technical developments. Early deployment would also enable a valid dialog between end users and developers.

6. CONCLUSION

The long-term approach in a realistic setting has enabled investigation of technical, tactical, ethical, organizational, and human-robot interaction issues out of the users' perspective. Gathered data became more uniform over time, indicating the validity of the end results and their ability to serve as a foundation for future work. However, it should be remembered that training maneuvers target the most engaging task rather than the most common in active duty missions.

The study has showed that the MOUT-units rely on precise and thoroughly trained actions that can be executed with high precision and a minimum of ambiguity. The importance of reliability increases with risk and uncertainty. Time is often a critical issue, and means of communication are often sparse. All MOUT-gear must be portable as many of the missions are performed on foot; ruggedness and weight are important issues. Equipment must function regardless of weather or time of day.

Deploying the Packbot in MOUT is a two-person task for both physical and mental reasons. The most common mission was *combat reconnaissance* in buildings when enemy presence was uncertain and time was not critical. The main benefits were reduced risks for own troops and civilians, as well as a decreased weapon deployment. The users were of the opinion that units assigned to high-ambition tasks in urban settings should be equipped with one UGV per platoon.

The range of the radio link, the video feedback, and the design of the operator control unit were the features constraining the system's overall performance the most. Other properties of the system, such as ruggedness, size, weight, terrain ability, and endurance did, on the other hand, prove adequate to the application. Trials with payloads indicated that the system has potential for more frequent deployment if extended with modular add-ons for enhanced sensing, voice communication, and weapons deployment. Integration with other military equipment must be a consideration for the future design of robots.

The question of beneficial deployment is, however, beyond just technical functionality. The introduction of robotics as a tool to infantry soldiers may be comparable to automatic rifles or portable radios. Implementing a device with such novel functionality will require tactical development beyond what is normally accomplished. Those who begin implementation now will not only gain the benefits of today's available systems, but also be able to perform tactical development parallel to ongoing technical development, and thereby shorten the time to deployment of the next robot generation with years.

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