Exploring the Ethical Landscape of Robot-Assisted Search and Rescue

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Abstract: As robots are increasingly used in Search and Rescue (SAR) missions, it becomes highly relevant to study how SAR robots can be developed and deployed in a responsible way. In contrast to some other robot application domains, e.g. military and healthcare, the ethics of robot-assisted SAR are relatively under examined. This paper aims to fill this gap by assessing and analyzing important values and value tensions of stakeholders of SAR robots. The paper describes the outcomes of several Value Assessment workshops that were conducted with rescue workers, in the context of a European research project on robot-assisted SAR (the TRADR project). The workshop outcomes are analyzed and key ethical concerns and dilemmas are identified and discussed. Several recommendations for future ethics research leading to responsible development and deployment of SAR robots are provided.

Keywords: Roboethics, Search and Rescue robotics, Human-Robot Interaction, ethical concerns, values, Value Sensitive Design.

1. INTRODUCTION

With advancements in AI and robotics, robots that share an environment and interact with people are becoming ubiquitous. This development has fueled a growing realization that ethics of human-robot interaction needs to be addressed, evidenced by a growing number of publications, workshops and conferences addressing roboethics (Wallach and Allen, 2008; Lin et al., 2011; Murphy and Woods, 2009; Malle et al., 2015). As Riek and Howard (2014, page 5) put it “One especially wants to avoid giving the impression that it is the responsibility of the ethicist to instruct scientists and engineers on what they may and may not do. Ethics should, instead, be understood as making a constructive contribution to work in HRI”. To foster this development, a code of ethics and practical guidelines have been proposed for robot engineers and HRI practitioners (Ingram et al., 2010; Riek and Howard, 2014; Murphy and Woods, 2009).

For some domains, ethical concerns regarding the application of robots have received a lot of attention (Łichocki et al., 2011), e.g. in the military domain, car industry, healthcare and education. However, in the field of Search and Rescue (SAR) it appears that ethics related to the use of robots has not so much been addressed; indeed, it is telling that in the EURON Roboethics Roadmap (Veruggio, 2006) SAR robots are only mentioned as a subcategory of ‘outdoor robots’. Ethics and values are relevant for responsible development (e.g., requirements) and deployment (e.g., working agreements) of SAR robots. In this paper, we therefore provide an exploration of the ethical landscape surrounding robot-assisted SAR missions.

We explore the ethical robot-assisted SAR landscape by identifying and analyzing humans values (e.g. trust, autonomy and privacy) and value tensions. Value tensions refer to situations in which technology supports one value while at the same time hinders another; as such they are indicators of potential ethical dilemmas. Our approach is inspired on the Value Sensitive Design (VSD) methodology, which accounts for human values throughout the design process (Friedman et al., 2013). We conduct a series of three Value Assessment workshops with SAR workers – in this case firefighters – in which we make use of VSD methods to assess and analyze the stakeholders and their values in the SAR field. Using the workshop results, literature and experiences in the TRADR project, we identify key ethical concerns and dilemmas for the robot-assisted SAR field.

In this paper we first provide a description of the robot-assisted SAR domain. Then, we briefly summarize ethical themes in different robot application fields that are relevant to SAR. We then describe the setup and execution of the Value Assessment workshops, and the workshop outcomes (stakeholder values and value tensions). From these outcomes, we derive and discuss several main ethical concerns and dilemmas specific to robot-assisted SAR.

2. BACKGROUND

2.1 *Robot-Assisted Search and Rescue*

The SAR domain is a unique area of application because it inherently entails an unstructured (often destructed) environment, that is commonly hazardous for both people and equipment. Particularly for first-response missions, work is typically done under time pressure (every minute can count) and in harsh conditions; this can lead to physical and/or mental strains on rescue workers, increasing the risk of developing psychiatric and post-traumatic distress (Fullerton et al., 1992; Chang et al., 2003; Bos et al., 2004). SAR can also happen over prolonged periods of time (days, weeks, months) as part of ongoing disaster response. These domain characteristics entail some specific ethical considerations, e.g. what is morally acceptable to ask from rescue workers in terms of mental and physical well-being when lives are at stake. Work specifically addressing the ethics of disaster response is hard to find, but some guidelines exists, e.g. the Council of Europe's "Ethical principles on disaster risk reduction and peoples resilience" (Prieur, 2012) specifically dictates how rescue workers should behave ethically, as well as specifying that rescue workers should have access to psychological assistance during and after disaster response missions. Other work has discussed the ethics of disaster management (Geale, 2012), drawing parallels with ethics of humanitarian aid, while others specifically address ethics of firefighters (Sandin, 2009), comparing it with the ethics of the medical profession.

Generally, the SAR domain is perceived as an application area in which robots can provide a valuable contribution. Robots are capable of traversing areas that are inaccessible for humans, may carry elaborated sensory equipment beyond human capabilities (e.g. infrared) and can provide unique perspectives (e.g. aerial view) contributing to situation awareness. There exists a large body of research addressing the employment of SAR robots (Murphy, 2014), along with actual application in the field (Murphy, 2004; Murphy et al., 2012).

The types of robots that are employed in SAR environments are quite various; common types include Unmanned Ground Vehicles (UGV), carrying a variety of sensors (e.g., laser range finder, video, audio, infrared) and typically equipped with tracks to navigate unstructured terrains (see Figure 1), and Unmanned Aerial Vehicles (UAV) that can provide high-level (aerial) view of the disaster area. Generally, robots are employed in search areas that are inaccessible for humans because they are too dangerous, or because of physical constrains (too small, too high). As of today, robots are always controlled by human operators (human-in-the-loop), but some functionality is becoming (partially) autonomous (Birk and Carpin, 2006; Okada et al., 2011; Zuzánek et al., 2014).

Fig. 1. The TRADR UGV operating during an exercise aimed to capture a SAR context.

Interaction between humans and SAR robots can happen in a number of distinct manners. Humans interact with robots as operators, as infield-rescuers or as victims, each yielding different types of HRI. For instance, robots controlled by an operator are embedded within a clear hierarchical structure, but when robots encounter a victim during a mission, the human is in some way dependent on the robot, e.g. the robot supports evacuation of victims by lifting and carrying them.

2.2 *Roboethics*

There are many sorts and types of robots (e.g. military, surveillance, service, educational and entertainment robots), and they are used in diverse application domains. Different robot types and application domains pose their own design challenges and ethical concerns (Łichocki et al., 2011).

There is some work addressing robot ethics against a backdrop of the SAR domain. For instance, Kruijff and Janíček (2011) propose a method of modeling accountability in human-robot teams, thus endowing artificial systems (robots) with some form of moral accountability. However, to the best of our knowledge there is relatively little work explicitly addressing the ethics of robot-assisted SAR. In order to get a better grip on the ethical concerns regarding SAR robots, we therefore discuss ethics surrounding the use of robots in the healthcare and military domain. There is a considerable amount of work on roboethics in these domains, and both have links with the SAR domain (healthcare resembles victim care in SAR, and military as well as SAR robots are used in rough and unknown terrains to perform reconnaissance and search for targets).

Robots in healthcare are used for different tasks, which are often categorized as monitoring, housekeeping, and companionship tasks (van Wynsberghe, 2013; Sharkey and Sharkey, 2012; Decker, 2008; Butter et al., 2008). Monitoring tasks involve, for instance, keeping track of someone's physical activities or medicine intake, and detecting abnormal or dangerous situations. Housekeeping and assistance tasks include cleaning, washing, carrying objects, and serving food and drinks. Examples of companionship activities are displaying emotions, responding to emotion and touch, talking and playing. An ethical concern related to these robot activities includes the issue of responsibility for a robots (failed) actions, e.g. who is responsible if a robot harms a patient or provides wrong medical advice? Another concern involves privacy, e.g. who has access to the data that a robot collects about a patient, and under what circumstances? Also, what consequences does a robot that serves as a companion have for human-human contact? It is particularly important to address these issues because healthcare robots often interact with vulnerable groups of people such as patients, elderly or children.

Military robots serve on the ground as stationary robots or unmanned ground vehicles (UGVs), in the air as drones, unmanned aerial vehicles (UAVs) or remotely piloted systems, and on or under water as unmanned ships or submarines. Task performed by military robots include monitoring, navigating, carrying, target tracking and firing. Proponents of military robots see them as a way to relieve humans from dull, dirty and dangerous tasks, and sometimes also as a way to improve performance (Arkin, 2009). Others, however, are concerned about shifting control from humans to robots, in particular if this includes the application of lethal force (Lucas Jr, 2011; Sparrow, 2007). Nowadays, most military robots are still tele-operated by human operators, but the development towards more automation has been debated in media, politics and academia, most notably in the form of the campaign 'Stop Killer Robots' (Docherty, 2012). These discussions concern issues of responsibility for robot behavior, and psychological effects of military robot use on the enemy, robot (drone) operators and civilians in war zones (Lin et al., 2009).

3. VALUE ASSESSMENT WORKSHOPS

We performed three workshops to assess values that play an important role in robot-assisted SAR. The workshops were conducted during an end-user meeting of the TRADR project that was held in Pisa in September 2014. The Value Assessment workshops were inspired on Value Sensitive Design (VSD) methods. In this section we provide some background on the TRADR project and VSD; subsequently, we describe the setup of the workshops and provide the results.

3.1 *The TRADR project*

The *Long-Term Human-Robot Teaming for Robot-Assisted Disaster Response* (TRADR) project[1] aims to develop robots that are able to provide assistance during disaster response missions, working alongside human rescue workers as team-members rather than as tools (Kruijff-Korbayová et al., 2015). A TRADR team is comprised of human rescue workers (team leader, robot operators, infield rescuer), UGVs and UAVs. Three firefighting brigades (Dutch, German and Italian) represent SAR end-users and are part of the TRADR consortium. A yearly development cycle – including exercises and evaluations with end-users – contributes to align the project towards employment in the field.

As a disaster response mission may last days, months or even years, within TRADR there is an emphasis on building persistent models of the environment, multi-robot action and human-robot teaming. Towards this end, both low-level robot control aspects and higher-level human-robot teaming aspects are addressed. Particularly the latter entails a (re)definement of the roles that robots may play within a search and rescue team. A robots assigned role, its capabilities, its appearance and its behavior will influence expectations that people interacting with the robots have. As the role that robots play in SAR teams changes – e.g. by enabling robots to act responsibly in a team and by endowing them with social intelligence (Fincannon et al., 2004) – moral expectations may become heightened, potentially up to levels not achievable by the robots.

3.2 *Value Sensitive Design*

VSD is a "theoretically grounded approach to the design of technology that accounts for human values in a principled and comprehensive manner throughout the design process" (Friedman et al., 2013). VSD defines values as "the things that people or groups of people consider important in life".

Important concepts in VSD are stakeholders, values and value tensions. A distinction is made between direct and indirect stakeholders of a system. Direct stakeholders interact directly with the system or its output, and indirect stakeholders are impacted by the system without interacting with it directly. Stakeholders have values. Values that play a role in the design of technology are, for instance, autonomy, security, privacy, safety, trust, responsibility, sustainability, and fun. Value tensions occur when a particular design of a system supports one value, but hinders another. For example, supporting the value of security, e.g. by placing more surveillance cameras, may hinder privacy.

VSD contains a rich collection of methods and techniques that allow designers to account for human values throughout the design process. There are methods to e.g., identify and analyze value tensions (Miller et al., 2007), promote envisioning of long-term influence of new technology (Friedman and Hendry, 2012), and

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[1] http://www.tradr-project.eu

identify requirements that account for values (Harbers et al., 2015).

3.3 *Setup of the workshops*

Three Value Assessment workshops were organized to explore values at stake in the robot-assisted search and rescue domain. The specific order of the activities in the Value Assessment workshops is new, but all activities are based on existing VSD methods.

The workshop participants were all professional firefighters from the *Corpo Nazionale Vigili del Fuoco*, the Italian national firefighting organization. They were from different levels in the organization (both officers and field workers), and none of them worked with robots in their daily work. The three workshops had 12, 8, and 3 participants, respectively.

All three workshops contained the following three steps: a) identify stakeholders, b) identify values for each stakeholder (group), and c) examine the relation between stakeholder values and search and rescue robots. Step a) involved the identification of both stakeholders that interact with the robots and those that do not interact with them, but are affected by the robots. In step b), values were identified for each stakeholder, where values had to be important for the stakeholders in that specific role. For instance, a fire-fighter may value both safety and friendship, but in the role of a fire-fighter, safety is more important than friendship. In step c), the relation between values and technology was considered by identifying positive and negative effects of search and rescue robots on each stakeholder value. This last step serves to provide context to the stakeholder values, and make clear how they can be affected by SAR robots.

Due to practical reasons, the three workshops differed in duration (4, 2, and 2 hours, respectively), and because of that, only the participants of the first workshop identified value tensions (in addition to that, they also created a mind map of “Disaster Response” and prioritized the importance of different values). Although there were some differences between the workshops in number of participants, duration and activities, we believe this had no particular impact on the results, and therefore we aggregated the outcomes over all workshops.

3.4 *Workshop Outcomes*

Table 1 provides an overview of the stakeholders and values that were identified in the workshops. Other relevant values and stakeholders – that were not mentioned by the workshop participants – may exist, but here we only report the workshop outcomes. Regarding the relation between technology and stakeholder values, considerably more positive than negative effects of SAR robots on stakeholder values were identified. We provide a few representative examples of relations between stakeholder values and technology below.

Personal safety, for instance, was identified as a value of both firefighters and victims. For firefighters, only positive effects of SAR robots on this value were identified: SAR robots make it possible for firefighters to stay away from dangerous situations. For victims, however, positive and negative effects were identified. On the one hand, it was said that robots can find and rescue victims, but on the other hand, they may be dangerous for victims, e.g. if they have inflammable batteries or when they fly or drive into a human.

Another example is the value of health for paramedics. This value is supported by SAR robots in the sense that robots can provide information about the physical state of victims, e.g. blood circulation, breath, and heart rate. But at the same time, the value is hindered because robots cannot provide health information about victims of the same quality as a human would provide.

A final example is that SAR robots were also thought to have a positive effect on local authorities’ value of sharing information; e.g., robots allow local authorities to provide more information about the situation to press, citizens and family of victims.

Table 1. Workshop outcomes

Stakeholder	**Values**
firefighter	personal safety, safety of others, access to information, well-being, effectiveness, ease of use, authority
victim	personal safety, health, well-being, access to information, contact
paramedic	personal safety, access to information, contact, health, well-being
policemen	personal safety, security, neutrality, effectiveness, courage, security, trust, access to information
press	impartiality, transparency, access to information
local authorities	access to information, sharing information, safety, healthy finances
observers	curiosity, safety
electricity company	access to information, safety

3.5 *Value tensions*

Value tensions involve conflicts between values of different stakeholders groups, values of one stakeholder group, or one value of one stakeholder group (which can become threaded in the wake of introducing new technology) Miller et al. (2007). In this subsection, we discuss the value tensions regarding the deployment of SAR robots that were identified by the workshop participants. As such, they represent the stakeholders’ view and indicate where potential conflicts – that are important from their perspective – may arise. Some scenarios – e.g. what happens when SAR robots are armed – are hypothetical and unlikely to occur; we nevertheless include these as they are part of the result.

Hindering vs supporting safety. Robots can both support and hinder the safety of the people that encounter them, such as victims and rescue workers. On the one hand, robots can improve the search and rescue operation. But on the other hand, they can be dangerous, for instance, when they fail to identify a human being and collide (flying or driving) with the human. Also, equipping robots with weapons and ammunition may support the safety of search and rescue workers or policemen, but may hinder the safety of victims or other people encountered by the robot.

Safety vs well-being. The deployment of robots can support safety of victims by making the SAR operation faster and more effective, but it can hinder the victims well-being. For example, it may be a shocking experience to be trapped, wounded and lost, and suddenly be confronted with a robot, in particular, if there are no humans around. There may also be victims that do not want to be saved by a robot.

Effectiveness of firefighter vs police. SAR robots can be deployed for a lot of different activities. When there is a limited amount of robots, choices have to be made regarding their deployment. In such situations, for instance, deploying a robot for activities of the fire brigade hinders effectiveness of policemen, and vice versa. This tension may also occur within one stakeholder group, e.g. firefighters, when the group is divided into sub-teams, and there are not sufficient robots for all sub-teams.

Transparency vs privacy. Robots make it possible to collect more information of a disaster through their cameras and other sensors. Transmitting this information to the press supports transparency, as it allows the press to better inform the public about the situation at hand. However, it may happen that privacy sensitive information about victims is spread this way, e.g., when family members learn about a victims situation through media rather than through personal conversation.

Safety and effectiveness vs healthy finances. Deployment of robots can increase the safety and effectiveness of rescue workers during a disaster response situations. However, the purchase of robots may be expensive and hinder the local authorities value of healthy finances.

Transparency and access to information vs well-being. Robots make it possible to collect more information of a disaster. Spreading this information can support transparency and access to information for the public and other stakeholders. But at the same time, it may hinder well-being by scaring people and creating unnecessary panic.

4. ETHICAL CONCERNS AND DILEMMAS IN ROBOT-ASSISTED SAR

In the previous section we described the outcomes of the Value Assessment workshops. In this section we combine the workshop outcomes with insights obtained from our work in TRADR project (e.g. from interacting with different stakeholders, observing them when they interact with robot technology) and insights obtained from the literature, identifying risks for the SAR domain that can lead to ethical dilemmas. We do that by grouping similar concerns (potential negative effects of technology on values and value tensions), and then including those concerns that either turned up multiple times, e.g. within the workshops or in both a workshop and in the literature, or that are considered essential based on literature on roboethics.

Our analysis results in the following six main ethical concerns that are relevant to the SAR domain: 1) safety risks, 2) decreased performance due to replacement of humans, 3) loss of relevant information, 4) false expectations about robot capabilities, 5) loss of privacy, and 6) responsibility assignment problems. The first five concerns are directly derived from the workshop outcomes, though we rephrased some of them to make them more generally applicable to SAR robots. We added the last concern, responsibility assignment problems, as it is often discussed in literature on roboethics (e.g. (Noorman and Johnson, 2014)), and it may also apply to SAR robots. All of the concerns may also apply to the use of robots in other domains, but in this section we discuss how they apply to the SAR domain specifically. In addition, we highlight ethical dilemmas related to these risks (listed in Table 2).

Safety risks. One of the main objectives of SAR is to bring people into safety, and the field inherently has to deal with safety risks. SAR robots can reduce a lot of these risks, most notably, when robots instead of rescue workers explore dangerous areas to search for and rescue victims. The introduction of SAR robots, however, also yields new safety risks, where we make a distinction between safety risks *within* and *beyond* a single search and rescue mission.

Risks due to robot use within a SAR mission are caused by potential malfunctioning, or otherwise inappropriate behavior of the robot. A SAR robot, for instance, can break down, cause collisions in unstable buildings, or drive or fly into a human. Even if the robot is technically performing sound, its behavior can still be harmful due to its interaction with the environment. This poses dilemma #1: *should SAR robots be employed when they might help saving lives, but their application might also lead to casualties?*

Safety risks that reach beyond the scope of single missions are related to possible dual use of SAR robots.

The technology developed for robot-assisted SAR – while not being intended to – is often also applicable in military domains, where the aim may be killing rather than rescuing people. This is the case because characteristics of SAR missions are to a large extent very similar to war zone missions, i.e. performing reconnaissance, providing tactical overview, searching for persons using a variety of sensors and information sources in rough, unstable and unpredictable terrains. Thus, this poses dilemma #2: *should one develop SAR technology that is intended for peaceful purposes even when it has clear military potential?*

Decreased performance due to replacement of humans. The application of SAR robots can lead to a reduction in the number of human (infield) rescue workers. As of to date, robots are generally perceived as an addition to SAR missions. But once a technology is in place, it is not inconceivable that robots – in certain situations – may be used as substitutes for, rather than additions to, human rescue workers. This is likely to happen especially in those situations that pose high risks on human rescue workers, but are currently deemed acceptable.

Replacement of humans by robots may lead to degraded performance with respect to victim contact, situation awareness, manipulation capabilities, etc. For instance, a robot may scare a victim who is not expecting a robot, or does not recognize it as a benign SAR robot. Even though the robot would be equipped with social capabilities or mediate contact between a victim and rescue workers at a distance, it would probably not be able to calm the victim as much as a human would.

Another example of degraded performance due to robots replacing rescue workers is that mediated contact may make it harder for medical personnel to perform triage or provide medical advice and support. The potential replacement of human workers by robots yields the following dilemma #3: *should one replace infield workers by robots if that leads to suboptimal performance?*

Loss of relevant information. A great benefit of SAR robots, in particular drones, is that they make it possible to collect large amounts of information, including information that was otherwise inaccessible. However, this introduces a new dilemma. Rescue workers have limited momentary cognitive capacities, and the large quantity of information, the ad-hoc nature of the operation, and the limited time of rescue workers in emergency situations make it impossible for them to inspect all the information. In order to use the information collected by robots, it needs to be automatically processed into more manageable pieces of information, e.g. by aggregating or filtering data. There is a risk that in this process relevant information is lost. Thus, on the one hand, processing information can improve performance, but on the other hand, it can also cause rescue workers to miss relevant information, which they would have noticed when not relying on SAR robots.

An example of data processing is to use images collected by drones for automated victim detection. Such technology may increase performance, but could also lead to failing detection or false positives. This yields dilemma #4: *to what extent should information collected by robots be processed to make it more digestible at the risk of losing information?*

False expectations about robot capabilities. Stakeholders may not be able to make appropriate judgments regarding the capabilities and limitations of rescue robots, which can lead to two potential risks. On the one hand, stakeholders may overestimate the capabilities of SAR robots, which may yield false hope for victims, deployment of robots for tasks for which they are not suitable, and unjustified reliance on their performance, e.g. expectations that a robot will infallibly detect victims. On the other hand, stakeholders may underestimate a robot's capabilities, which can lead to unnecessary worries, and robots not being used to their fullest. Adequate training may contribute to more realistic expectations, thus partially solving this problem, but this may not necessarily be accessible for all stakeholders. This entails dilemma #5 : *should one deploy robots, knowing that this may raise false expectations and runs the risk of degraded performance?*

Loss of privacy. The use of robots generally entails an increase in information gathering, which can potentially lead to privacy loss. This may concern personal information of rescue workers, e.g. their physical and mental stress levels, or victims, e.g. (images of) their physical condition. It can also apply to inhabitants of a disaster area, e.g. when drones collect images of their living area. If a search and rescue operation is performed in a public or semi-public building, robots may encounter personal information about employees or maybe even classified information.

Potential loss of privacy because of robot use does not necessarily result in an ethical dilemma, as it can be argued that due to the critical nature of a SAR mission, the benefits of collecting information largely outweigh the harm it may cause. This presumes, however, that the information is handled carefully, i.e. it should stay within professional rescue organizations, and only be used for SAR purposes. Because the robot-assisted SAR typically happens in a time-critical, data-rich, high-stakes and possibly quite chaotic environment, particular care regarding privacy is appropriate.

Table 2. List of ethical dilemmas identified
for robot-assisted SAR.

#	Dilemma
1	Should SAR robots be employed when they might help saving lives, but their application might also lead to casualties?
2	Should one develop SAR technology that is intended for peaceful purposes even when it has clear military potential?
3	Should one replace infield workers by robots if that leads to suboptimal performance?
4	To what extent should information collected by robots be processed to make it more digestible, at the risk of losing or misrepresenting information?
5	Should one deploy robots, knowing that this may raise false expectations and runs the risk of degraded performance?
6	Should one deploy robots that may yield responsibility assignment problems?

Responsibility assignment problems. Responsibility assignment problems can apply to both moral and legal responsibility, where moral responsibility concerns the question 'Who is to blame when things go wrong?' and legal responsibility 'Who is accountable when things go wrong?' Such problems can arise when robots act independently, i.e. without human supervision. If the robot malfunctions, makes a mistake or causes harm, it may be unclear who is responsible for the damage caused: the operator, the programmer, the manufacturer or the robot itself. Responsibility assignment problems become particularly complicated when the robot has (partial) autonomy, self-learning capabilities, or is capable of making choices that were not explicitly programmed. As such, dilemma #6 is the following: *should one deploy robots that may yield responsibility assignment problems?*

5. CONCLUSION

In this paper we described the results of three Value Assessment workshops with rescue workers. We believe that the workshops provided an effective way to obtain insight in the main values and value tensions around SAR robots, and that it was particularly useful to address the perspective of not only direct but also indirect stakeholders. In future Value Assessment workshops, it would be beneficial to also involve indirect stakeholders and directly ask them for their perspective.

Based on the workshop results, we identified a list of key ethical concerns and dilemmas in the robot-assisted SAR domain. As future SAR missions will most likely involve more and more advanced robot technology, we consider it prudent to address these ethical concerns. Particularly because the SAR domain incorporates – quite literally – matters of life and death, addressing these issues are relevant and timely.

It is beyond the scope of this paper to provide actual solutions for the raised dilemmas. As such, they set a research agenda highlighting areas in need of further examination. Many of the dilemmas involve a trade-off between benefits due to using a robot versus increased risk of a particular negative outcome. In order to make considerate choices in such situations, insights and tools enabling appropriate risk assessments are needed. For instance, what is the change that a robot will stop working or cause a building to collapse? Which factors influence these risks? Currently, such estimates are often not very accurate or even impossible to make. Thus, next steps would be to make more accurate estimates of different risks associated to robot use in SAR missions.

The list of concerns and dilemmas presented in this paper is by no means intended to be comprehensive. However, we do believe that they address some of the main ethical questions in the robot-assisted SAR domain. This paper thus aims to foster discussions on roboethics in general and ethics of robot-assisted SAR in particular, and contribute to the development of the SAR domain as a whole.

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REFERENCES

Arkin, R. (2009). *Governing lethal behavior in autonomous robots*. CRC Press.

Birk, A. and Carpin, S. (2006). Rescue robotics a crucial milestone on the road to autonomous systems. *Advanced Robotics*, 20(5), 595–605.

Bos, J., Mol, E., Visser, B., and Frings-Dresen, M.H. (2004). The physical demands upon (dutch) firefighters in relation to the maximum acceptable energetic workload. *Ergonomics*, 47(4), 446–460.

Butter, M., Rensma, A., Boxsel, J.v., Kalisingh, S., Schoone, M., Leis, M., Gelderblom, G., Cremers, G., Wilt, M.d., Kortekaas, W., et al. (2008). Robotics for healthcare: final report.

Chang, C.M., Lee, L.C., Connor, K.M., Davidson, J.R., Jeffries, K., and Lai, T.J. (2003). Posttraumatic distress and coping strategies among rescue workers after an earthquake. *The Journal of nervous and mental disease*, 191(6), 391–398.

Decker, M. (2008). Caregiving robots and ethical reflection: the perspective of interdisciplinary technology assessment. *Ai & Society*, 22(3), 315–330.

Docherty, B.L. (2012). *Losing Humanity: The Case Against Killer Robots*. Human Rights Watch.

Fincannon, T., Barnes, L.E., Murphy, R.R., and Riddle, D.L. (2004). Evidence of the need for social intelligence in rescue robots. In *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, volume 2, 1089–1095. IEEE.

Friedman, B. and Hendry, D. (2012). The envisioning cards: a toolkit for catalyzing humanistic and technical imaginations. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Sys-*

tems, 1145–1148. ACM.

Friedman, B., Kahn Jr, P.H., Borning, A., and Huldtgren, A. (2013). Value sensitive design and information systems. In *Early engagement and new technologies: Opening up the laboratory*, 55–95. Springer.

Fullerton, C.S., McCarroll, J.E., Ursano, R.J., and Wright, K.M. (1992). Psychological responses of rescue workers: fire fighters and trauma. *American journal of orthopsychiatry*, 62(3), 371.

Geale, S.K. (2012). The ethics of disaster management. *Disaster Prevention and Management: An International Journal*, 21(4), 445–462.

Harbers, M., Detweiler, C., and Neerincx, M.A. (2015). Embedding stakeholder values in the requirements engineering process. In *Requirements Engineering: Foundation for Software Quality*, 318–332. Springer.

Ingram, B., Jones, D., Lewis, A., Richards, M., Rich, C., and Schachterle, L. (2010). A code of ethics for robotics engineers. In *Human-Robot Interaction (HRI), 2010 5th ACM/IEEE International Conference on*, 103–104.

Kruijff, G.J.M. and Janíček, M. (2011). Using doctrines for human-robot collaboration to guide ethical behavior. In *AAAI Fall Symposium: Robot-Human Teamwork in Dynamic Adverse Environment*.

Kruijff-Korbayová, I., Colas, F., Gianni, M., Pirri, F., de Greeff, J., Hindriks, K., Neerincx, M., Ögren, P., Svoboda, T., and Worst, R. (2015). Tradr project: Long-term human-robot teaming for robot assisted disaster response. *KI - Knstliche Intelligenz*, 1–9.

Łichocki, P., Billard, A., and Kahn Jr, P.H. (2011). The ethical landscape of robotics. *Robotics & Automation Magazine, IEEE*, 18(1), 39–50.

Lin, P., Abney, K., and Bekey, G.A. (2011). *Robot ethics: the ethical and social implications of robotics*. MIT Press.

Lin, P., Bekey, G.A., and Abney, K. (2009). Robots in war: issues of risk and ethics.

Lucas Jr, G.R. (2011). Industrial challenges of military robotics. *Journal of Military Ethics*, 10(4), 274–295.

Malle, B.F., Scheutz, M., Arnold, T., Voiklis, J., and Cusimano, C. (2015). Sacrifice one for the good of many?: People apply different moral norms to human and robot agents. In *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction*, HRI '15, 117–124. ACM, New York, NY, USA.

Miller, J.K., Friedman, B., Jancke, G., and Gill, B. (2007). Value tensions in design: the value sensitive design, development, and appropriation of a corporation's groupware system. In *Proceedings of the 2007 international ACM conference on Supporting group work*, 281–290. ACM.

Murphy, R.R. (2004). Human-robot interaction in rescue robotics. *IEEE Transactions on Systems, Man, and Cybernetics, Part C*, 34(2), 138–153.

Murphy, R.R. (2014). *Disaster robotics*. MIT Press.

Murphy, R.R., Dreger, K.L., Newsome, S., Rodocker, J., Slaughter, B., Smith, R., Steimle, E., Kimura, T., Makabe, K., Kon, K., Mizumoto, H., Hatayama, M., Matsuno, F., Tadokoro, S., and Kawase, O. (2012). Marine heterogeneous multirobot systems at the great eastern japan tsunami recovery. *Journal of Field Robotics*, 29(5), 819–831.

Murphy, R.R. and Woods, D.D. (2009). Beyond asimov: the three laws of responsible robotics. *Intelligent Systems, IEEE*, 24(4), 14–20.

Noorman, M. and Johnson, D.G. (2014). Negotiating autonomy and responsibility in military robots. *Ethics and Information Technology*, 16(1), 51–62.

Okada, Y., Nagatani, K., Yoshida, K., Tadokoro, S., Yoshida, T., and Koyanagi, E. (2011). Shared autonomy system for tracked vehicles on rough terrain based on continuous three-dimensional terrain scanning. *Journal of Field Robotics*, 28(6), 875–893.

Prieur, M. (2012). Council of Europe. European and Mediterranean Major Hazards Agreement (EUR-OPA). `http://www.preventionweb.net/english/professional/publications/v.php?id=26384`. [Online; accessed 17-06-2015].

Riek, L.D. and Howard, D. (2014). A code of ethics for the human-robot interaction profession. *Proceedings of We Robot*.

Sandin, P. (2009). Firefighting ethics: Principlism for burning issues. *Ethical Perspectives*, 16(2), 225–251.

Sharkey, A. and Sharkey, N. (2012). Granny and the robots: ethical issues in robot care for the elderly. *Ethics and Information Technology*, 14(1), 27–40.

Sparrow, R. (2007). Killer robots. *Journal of applied philosophy*, 24(1), 62–77.

van Wynsberghe, A. (2013). Designing robots for care: Care centered value-sensitive design. *Science and engineering ethics*, 19(2), 407–433.

Veruggio, G. (2006). The euron roboethics roadmap. In *Humanoid Robots, 2006 6th IEEE-RAS International Conference on*, 612–617. IEEE.

Wallach, W. and Allen, C. (2008). *Moral machines: Teaching robots right from wrong*. Oxford University Press.

Zuzánek, P., Zimmermann, K., and Hlavác, V. (2014). Accepted autonomy for search and rescue robotics. In *Modelling and Simulation for Autonomous Systems: First International Workshop, MESAS 2014, Rome, Italy, May 5-6, 2014, Revised Selected Papers*, volume 8906, 231. Springer.