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How to Manage the Safety of Service Robots Operating in Coexistence With Demented Patients

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ABSTRACT

The developing elderly wave is expected to give a considerable demand for robotic solutions in the elderly care, especially in the nursing homes, to compensate for the lack of human resources required to maintain the quality of the elderly care services. Thus, social service robots are expected to fill an important role in the future, by providing services like logistics, remote medical consultations, entertainment, physical training etc. However, new challenges appear when introducing service robots in an environment where residents with impaired cognitive skills, coexist with service robots. This, especially, since the patients cannot take care of themselves, and are formally NOT responsible for any unfortunate safety conflicts. Thus, compared to operating in e.g. a normal restaurant, a service robot in a in a nursing home requires additional attention to the risks mitigation to ensure a safe operation. This includes analysis of both additional physical risks in addition to new, interperceptual risks. This paper addresses the complexity of fulfilling the required safety of service robots operating in nursing homes, and an extended risk mitigation methods is suggested in order to minimize the unavoidable, residual risk.

Keywords: Elderly care, Robotics, Human-robot interaction, Safety

INTRODUCTION

Robots are today mostly associated with industrial applications where the industrial robots operate inside physical fences, ensuring the safety. However, during the last years, open factories have become popular (Kluy et al., 2021). These requires a higher level of risk mitigation and safety certification of the robots to guarantee a safety coexistence with humans. The open factories have put attention to the perceived safety because the robots may cause fair and stress (Akalin et al., 2022; Kluy et al., 2021). Additionally, this knowledge has been developed further enable a harmonic coexistence between service robots and humans in public areas (Hung at al., 2022; Salvini et al., 2020; Servaty et al., 2020; Christoforou et al., 2020; Holland et al., 2021; Eggleston et al., 2021).

The current demographic development with "the elderly wave" forecast a huge lack of care givers during the next years. Only in a small country like Norway, with a population of 5.5 million people, the gap will be lack of more than 40 000 nurses (Figure 1) in elderly care already in 2035 (Thomas et al., 2020). In the European Union, the gap is expected to be even more challenging.

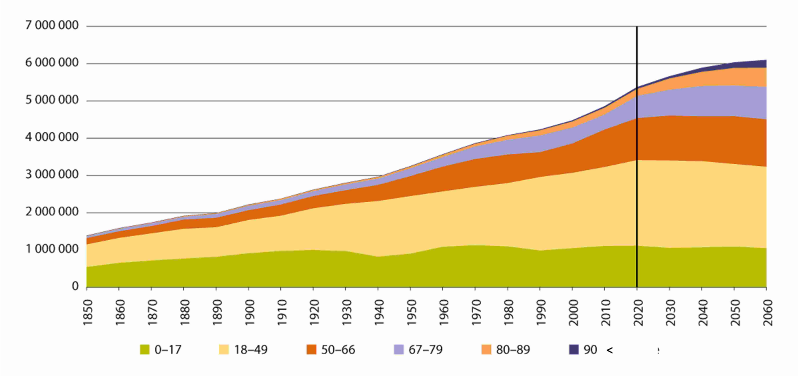

Figure 1: The "elderly wave" in Norway (Thomas et al., 2020).

The application of modern IT and robot technology are among the few measures that can solve the resource challenge in the elderly care. A smart utilization of this, will release more time for value added work; hence, care and medical treatment of the residents.

This has led to a request for a new generation service robots for nursing homes, which can support the care workers and the patients with various services.

However, this rises new challenges related to the safety, and even though the service robot is certified according to a standard, like EN ISO 13482 (Salvini et al., 2022) for operating safely in an open, public environment, like a shop or a restaurant, this robot will not provide the required safety to operate inside a nursing home together with elderly people with impaired cognitive skills (Thomessen, 2024).

This paper considers the safety challenges that occurs, when applying service robots in nursing homes, and suggest a solution based upon an extension of the current standards and procedures.

Considerations About Safety When Operating in a Nursing Home

The intention of using service robots is to provide additional resources that perform the desired tasks carefully and efficiently. This requires that the robot should

- Run at *highest, possible speed* when executing the tasks
- Operate *closely to the human* when direct interacted tasks are accomplished

Initially, the focus was to maximize the performance of the robots, within the frame of safety, however, recently the attention is put both to the physical and the perceive safety. Thomessen et al. (2020), developed in the project SAM4ROB, a new safety concept under the vision "humans and robots in safe and harmonic coexistence". Thus, the focus was to provide the required safety, but in addition, to create a common understanding between the robots and the humans, in order to reduce the likelihood of safety conflicts.

Figure 2: Special risk case: a person has fallen to the floor.

The following two terms were used:

- *Physical safety*, or *Safety*; represented by measures to protect the humans against injuries
- *Comfort*; represented by measures to enhance the perceived safety, and reduce the likelihood of unexpected safety conflicts between the human and the robot

Basically, the physical safety, required one of the two basic requirements to be fulfilled (RIA, 2014):

- All safety related hardware and software must be *fail-safe*, in practice redundant
- Alternatively, the robot must be *intrinsically safe*, which is normally solved by limiting the performance of the servo motors

Figure 3: Special risk case: a person is leaning to the robot when it starts moving.

Furthermore, in order, to physically be able to operate a robot safely in practice, it's also required that the humans are responsible, like

- Wearing the required protective cloths
- Not climbing over or under the fences covering the robot !
- Not running or walking faster than 1.8m/s !
- Use their knowledge from the safety training, during the daily work
- Don't try to harm or destroy the robot

Figure 4: Special risk case: a dementia resident performs a harming action.

If any of these, latter conditions are violated by the human, he or she will be responsible for a potential accident.

In a nursing home, some additional risks must be considered:

- The residents cannot take responsibility for themselves. Thus, there is no "irresponsible behavior"
- Training of the residents cannot be done due other their impaired cognitive skills
- The residents have reduced stability, and may use a cane when walking

And, in addition to this complex risk situation, any fall may likely cause an irreversible injury, like a broken heap due to the elderlies' brittle bone structure.

Figure 5: Special risk case: a resident falls when being surprised by the robot.

Thus, regarding safety, the additional cases must be taken into account (Figure 2, 3, 4, 5):

- The robot may hit a cane, due to a blind zone of the safety sensors
- A resident may lean onto the robot, while the robot starts to move
- An accident may be caused because the residents become surprised or afraid of the robot's behavior
- A resident may have fallen on the floor
- A dementia resident may perform unexpected, violating actions. Thus, the robot must also be able to protect itself against harm

Figure 6: Emergency case: all robots must instantly be parked to ensure a free escape route.

This introduces two new, categories of safety measures:

- *Impaired-skill, Safety*; represented by measures to prevent the human in cases where the human's impaired physical skills may cause a risk
- *Interperceptual Safety*; represented by measures to prevent the human and the robot, against accidents due to unexpected behaviour of the human

Interperceptual safety requires functions that guarantee an appropriate response from the robot, to ensure both that the human is not injured, and that the robot is not harmed. Thus, also include functions complying with Asimov's third law:

"A robot shall avoid actions or situations that could cause it to come to harm itself".

Finally, the operation inside a nursing home, also requires preparation for emergency situations (Figure 6) caused by fire, accidents, sickness etc. In these cases, the robot must be prepared to make an immediate, sensible parking, to ensure free access.

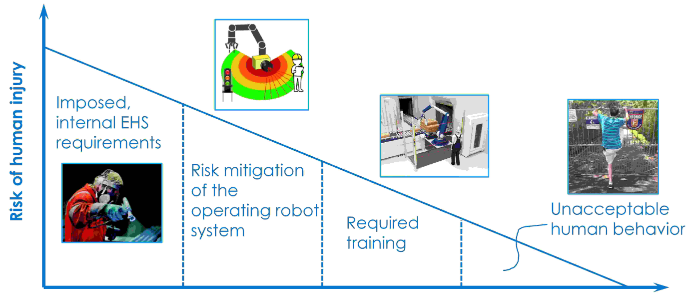

Figure 7: Risk conditions to be investigated during a normal risk assessment.

The Unavoidable Residual Risk

All products sold within the EU must be certified according to the CE standard and marked with the CE symbol, demonstrating that the product complies with The Machinery Directive (ECS, 2006). This includes a risk assessment of the product, like a robot, itself. However, when setting up the robot to perform a task, an additional a risk assessment of the application itself, is required according to ISO 12100 (ECS, 2010).

A typical risk assessment of a robot application, requires the risk mitigation to be considered in the following order (Figure 7):

i. Imposed, internal EHS requirements; represented by the imposed risk-reducing measures that must be followed when staying inside the premises, or carrying out a specific work task
ii. Risk mitigation of the robot system; represented by the necessary safety function of the system to prevent its use from causing a risk of injuries
iii. Training of the users; represented by a formal training, to give the users of the robot system the necessary knowledge to avoid injuries. NB! The steps above must be fulfilled as far as possible before training can be used as a risk-reducing measure
iv. Unacceptable human behavior; represented by unreasonable human behavior such as acts to commit suicide; climbing over the fences; crawl on the floor etc. NB! These risk factors need not to be to be taken into account during the risk mitigation of the robot system

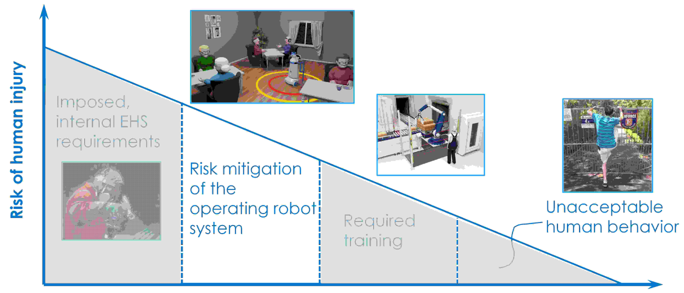

Figure 8: Risk conditions to be investigated during a risk assessment in a nursing home.

However, for a service robot operating in a nursing home, the risk situation, is significantly changed Figure 8), because

- There are no imposed EHS requirements for the residents, like wearing protective equipment or cloths
- Dementia residents can't be trained due to their impaired, cognitive skills
- There is no "unacceptable human behaviour" due to the residents' impaired cognitive skills

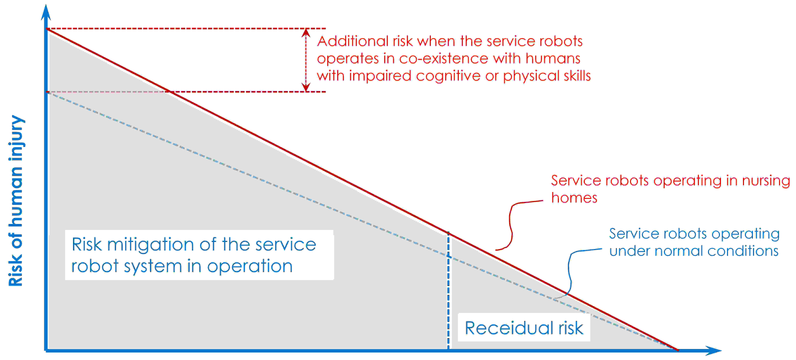

Figure 9: The unavoidable residual risk when applying robots in nursing homes.

Consequently, there will always be a residual risk when operating service robots in nursing homes. There are currently, no standards covering this, enhanced risk situation, except the conditions covered under the standard, ISO 13482 (RIA, 2020), describing the safety of service robots operating in a normal environment.

The Extended Risk Assessment for Robots in Nursing

Provided that the service robot is certified according to The Machinery Directive (ECS, 2006), and fulfil requirements specified in RIA (2020), or has built-in safety functions representing the same level of risk mitigation, the next step is to carry out an extended risk assessment to comply with the risk conditions in the nursing home. This, also to demonstrate and document that the residual risk is reduced to a minimum; thus,

- *Analyse* and document all potential risks, and apply a comprehensive risk assessment
- *Document* that state-of-the art safety technology is applied to reduce the risks to a minimum

During the risk assessment, the normal physical risks like collision etc. must be included. In addition, the following risks must be assessed:

- Risks due to *impaired mental and physical skills* of the residents
- Risks due to *instant illness*, falling etc.
- Risks due to the *perception* of the service robot, by the residents
- Risks due to *unexpected behavior* of the residents, due to dementia

After the risk assessment has been completed (Figure 10), the unavoidable residual risk must basically be covered by an insurance, providing the necessary human care, in case of accidents.

However, the challenge is to be able to do the necessary risk mitigation, while achieving the required performance, and thus, the benefit of the service robot in operation. Basically, this a trade-off between the desired motion speed and proximity to the residents when proving services, and the accepted residual risk.

Risk assesement for service robot in nursing home

Danger	Phase	Unwanted incident	Likely consequence	Probable cause	Implemented hazard reduction measures	Consequence	Probability	Risk	Recommended hazard reduction measures	Comment
Collision with a patient	Operation	The robot crashes with the walking stick of a standing / moving patient	Fall and physical patient injuries (hip fracture)	A walking stick is not detected because a standing resident has placed it in a blind spot on the safety laser.	None	4	3	12	None	Unavoidable residual risk
Collision with a patient	Operation	Collision with a walking patient	The robot stops and / or redirects its path	Potential collision between a walking resident and a moving robot	None	0	0	0	None	Part of the standard safety controller of the robot
Crushing hazard	Operation	Collision with a wheelchair that the resident is sitting in. The resident's hand is crushed between the robot and the edge of the wheelchair	A little pain in the patient's hand	An edge of a wheelchair is not detected because of the blind spot on the safety laser.	Limited power on the robot's motors	1	4	4	None	Tests have been carried out to ensure that the pain is insignificant
Unexpected motion	Operation	The robot starts moving when a resident is leaning on the robot's body	Fall and physical patient injuries (hip fracture)	There is no contact detection on the robot's body	None	4	3	12	AIRSKIN	AIRSKIN guarantees physical detection of the human
...	...	...	...	...	...	...	...	...	...	...

Figure 10: Example, cut from an extended risk assessment in nursing home.

CONCLUSION

Introduction of service robots in nursing has an important potential to enhance the welfare and compensate for the lack of health care workers. However, this creates new challenges related to safety, since many of the residents in the nursing homes have impaired cognitive skills, and thus, cannot take responsibility for themselves.

This paper considered these new challenges, and suggest an extended risk assessment, in order to reduce the residual risk to a minimum.

However, the residual risk cannot be eliminated, expect by moving the robot into a corner and shutting down the power.

Thus, an insurance is required to provide that any, even hypothetical risk, can be covered appropriately.

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