Ethical Guidelines for the Development of AI- Supported Healthcare Robots - with focus on the Patient Transfer Rehabilitation Robot

Franziska Kirstein, *Blue Ocean Robotics*

***Abstract*— Successful development and deployment of commercial robots is still a challenge, often reducing ethical considerations to safety issues. However, with the increased combination of robotics and artificial intelligence (AI), robotics companies should also be prepared to deal with ethics. This paper presents a project that aims to investigate what ethical issues healthcare robotics companies should foresee and consider when equipping their robots with AI features. The project uses a concrete example of a transfer and rehabilitation robot.**

I. Introduction

This paper presents a project that plans to investigate how ethics need to be considered when equipping a patient transfer and rehabilitation robot with artificial intelligence (AI) in the future. The project uses a concrete example of the Patient Transfer Rehabilitation (PTR) Robot developed by Blue Ocean Robotics. The robot has been developed to make the caregiver's work easier, more efficient and with higher quality. It is currently semi-autonomous and operated by healthcare professionals. In the future, it will be equipped with AI features to create a more autonomous and intelligent transfer and rehabilitation experience. The project presented in this paper aims at creating a set of ethical guidelines that healthcare robotics companies can use if they equip their robots with AI features.

II. Background

Rehabilitation robotics focuses on understanding and augmenting rehabilitation procedures through the usage of robotic technology. Research and development of robotic technologies for rehabilitation has received increasing interest over the last decades [1, 2, 3]. This is also due to the (expected) increase of elderly people leading to higher costs and concerns on the quality of rehabilitation and safety of healthcare professionals [4]. Hospitals spend high resources on patient handling and the risk of injuries is high for both, patients, and healthcare professionals. Research has for example shown that manual patient handling is not an effective way to reduce injuries to caregivers, due to the high risk of musculoskeletal overexertion. According to [5], most of the nursing staff's back-injury is preventable, leading to substantial savings to employers on medical and compensation costs.

The PTR Robot [Figure 1] has been developed to reduce healthcare professional's injuries and support them in their work, providing patients a higher quality of care. It provides a more efficient and flexible alternative, that integrates rehabilitation in the daily care routines. Differing from the existing manual patient hoists in the market or robotic rehabilitation devices such as the Andago [6] or Lokomat [7], the PTR Robot is movable and resizable, operated by a user interface. It fits into regular patient rooms, indoor rehabilitation areas as well as over the hospital beds, seats, and wheelchairs.

A. User-Centered Development of the PTR Robot

PTR Robots is the result of an innovation project between the Region Zealand University Hospital, Køge and Blue Ocean Robotics. Blue Ocean Robotics develops, produces, and sells professional service robots primarily in healthcare and hospitality. The development team consists of employees with multiple backgrounds: engineering, robotics, business, physiotherapy, design, and anthropology. Once a robot is ready to be commercialized, a spin out company is created. In this case, the spin our company is called PTR Robots. Blue Ocean Robotics is handling the design, development, and manufacturing of the robot whereas the spin out company is focusing on bringing the PTR Robot to the market.

The research and development process of the PTR Robot began in 2016 by mapping patient transfer situations and interviewing representatives of relevant caregiver groups. The close relationship between healthcare professionals and Blue Ocean Robotics has been kept ensuring optimal features in the robot. Feedback and input from hygiene experts, technical and clinical staff, patient representatives and IT/communication were also considered to develop the best possible robot to support the patient and optimal work environment for the caregivers.

In 2021, two PTR Robots were delivered to a University Hospital in Denmark for a test period. The systematic fieldwork revealed in advance that the daily rush in the wards, combined with the staff shifts, would challenge the learnings regarding the robot and, in consequence, would prevent the robot being used effectively. Hence, two main actions were planned to onboard and engage the users, also intending to keep the close relation and strengthen the mutual trust: a) introductory workshop with 98 healthcare professionals and b) "superusers" training. At the end of the sessions, a usability questionnaire was applied to the participants to quantify their

experiences into rates of usability, learnability, and acceptability of PTR Robot, which achieved positive results [8]:

- 92% of the participants agreed that PTR Robot is easy to use;
- 92% of participants agreed they would use PTR Robot again in their workplace:
- 85% of participants agreed that PTR Robot is quick to learn.

After the workshops and the training, the PTR Robots are still being used daily to collect input from healthcare professionals.

B. PTR Robot applications and use cases

Patient transfer and rehabilitation activities are resource intensive tasks in hospitals due to a constant patient flow with a high risk of work-related injuries and with low quality of patient experience. With the PTR Robot, it is not necessary to use different equipment for patient transfer situations and rehabilitation exercises. Thus, with just one device, healthcare personnel have the right equipment at hand, meaning less waiting and searching time. The ease-of-use supports the reduction of work-related injuries, repetitive strain injuries, sick day costs and resources. Use cases within patient transfer are e.g.:

- Turn and adjust positioning in bed: caregivers can easily turn or reposition patients in bed to prevent pressure ulcers or discomfort.
- From bed to wheelchair: patients can be transferred directly from bed to wheelchair either over the foot of the bed or expanding the robot over both the bed and wheelchair and transfer sideways with the travers.
- Transfer from stretcher to bed: if a patient is handled on a stretcher from e.g., an ambulance or operating theater, the patient can be transferred directly to a bed with the PTR Robot.
- Transfer to bathroom: the caregiver can transfer a patient to the bathroom to visit the toilet or take a bath. However, the robot cannot be used under the shower.
- On and off toilet: with the PTR Robot the caregiver can easily assist a patient on and off the toilet without having to change to several different assistive devices.
- Fall injury to secure positioning: if a patient experiences a fall injury, the caregiver can assist with the PTR Robot lifting the patient up and into a wheelchair or bed.

Compared to manual devices, the caregiver spends less strength on moving the patient and can thus focus on the interaction with the patient. The high flexibility ensures more active patient lifting, resulting in a more efficient rehabilitation process for the patient.

Figure 1. The PTR Robot

Using the PTR Robot in rehabilitation centers, it is possible to facilitate the strengthening of muscle tissue, balance, bone density and increased blood flow through safe and flexible sit-to-stand and gait training. More frequent rehabilitation is possible due to fewer resources needed in the training sessions, resulting in a faster and more efficient recovery. A variety of rehabilitation exercises, suited to fit everyone, are possible due to the high flexibility of the robot and the safe setting, creating an optimal work environment for the caregiver and the patient. Use cases within rehabilitation are e.g.:

- Gait training forward
- Gait training sideways, backwards and rotational
- Gait training with obstacles
- Balance training
- Sit to stand
- Core stability

C. Technical specifications of the PTR Robot

The PTR Robot is an intuitive battery-powered hoist lift designed to be controlled by one-single operator.[1] With the intuitive controlling system, it is easy to drive the robot around with only two fingers on the joystick [Figure 2]. It does not require any special training but can be used by every caregiver who is educated in patient transfer and rehabilitation. The caregiver can adjust both the height and the width enabling the robot to fit through a regular doorway or expand over both a bed and a wheelchair. The PTR Robot can displace a patient within the frame of the robot using the travers. This makes transfers from e.g., wheelchair to bed easier and more efficient.

The simple navigation system enables the caregiver to have

[1] For a visual representation of the PTR Robot and its technical specifications, please see https://www.youtube.com/watch?v=E1RmYLbtJAs

one hand free to support the patient. The caregiver can drive the robot in every direction and with light ease because of the omnidirectional wheels. It can also turn on its own axis making it easy to drive around in confined spaces. The robot is designed with 'push to operate' control that makes sure the robot's wheels are locking when the operator is not steering the robot. The robot is equipped with a perception feature that is displayed on the screen and activates the robot slowing down when detecting an obstacle or a person.

Figure 2. Top left: joystick to control robot movement. Top right: Omnidirectional wheels. Bottom left: Screen and panel to control traverse. Bottom right: remote control to operate lifting hoist

D. Equipping the PTR Robot with Artificial Intelligence

The PTR Robot is currently semi-autonomous and operated by healthcare professionals. In the future, AI features are planned such as autonomous navigation, general health assessment, intelligent and personalized rehabilitation support through e.g., emotion or voice recognition, gait analysis, body scans. These features will be developed together with both user types and based on their needs. For this, input from end-users of the PTR Robot is collected during feedback sessions or usability workshops. The user experience team at Blue Ocean Robotics is coordinating these activities and transforming feedback into requirements for new features. Together with the innovation and strategy team, these features are described, prioritized, and added to the roadmap. The features are then aligned with the developers and development is initiated. The development of new features at Blue Ocean Robotics is an agile process and therefore it is not possible to estimate what specific AI features will be developed in the future.

III. Motivation

The agile development process makes it necessary to take a closer look at the ethical issues that might arise through the introduction of such AI features. Foreseeing such ethical issues is challenging for all stakeholders involved in the development process. Research conducted on robotics development has shown that ethics is not a first concern of developers and often thought to be dealt with by personnel hired to deal with ethical issues [9]. Developers rather consider ethical issues in a technical approach connected with problem solving activities regarding e.g., safety issues [10].

This provided the motivation for Blue Ocean Robotics to investigate how to incorporate active ethical decision making in the development process when equipping the PTR Robot with new AI features in the future.

IV. Methodology

The project aims at investigating AI trends that will play an essential role in healthcare and the potential ethical implications when these trends become a reality. It is divided into four phases:

- Investigating AI trends that will play an essential role in healthcare and robotics.
- Envisioning how the PTR Robot can be equipped with AI technologies in the future to revolutionize patient transfer and rehabilitation.
- Highlighting and categorizing ethical issues arising in these future scenarios based on detailed workflow analysis.
- Creating a set of ethical guidelines.

The methodologies used to collect data include a mix of desktop research, expert interviews, and stakeholder workshops.

V. Expected Results

The project has just started and thus it is difficult to foresee ethical issues that could arise. However, in general these issues could be related to how AI and data will impact the organization, the workflow of the healthcare professionals and the way a patient receives treatment. Concrete examples are e.g., how data on patient transfer (how many transfers per day, how long each transfer takes place) will be handled by hospital management, whether emotion recognition works well enough in terms of gender and racial issues to offer every patient the same treatment or in how far the robot is influencing the healthcare professional in choosing a personalized rehabilitation program.

The outcome of the project will allow Blue Ocean Robotics to equip the PTR Robot with new functionalities while swiftly identifying ethical issues and addressing those. Thus, the project will support creating a more intelligent version of the PTR Robot, which is not only developed according to user needs, but also with ethical considerations in mind.

The results could potentially be re-used by other robotics companies and hopefully lead to a wider awareness of the importance of ethics in commercial robotics and AI. According to [11] ethical objections or moral concern of companies could potentially have an impact on reform or creation of the law. Robot companies could develop robots while respecting regulations and standards, but not fulfilling ethical requirements. However, more specialized laws around robot ethics could be beneficial for companies as they would

apply for all companies and offer clear regulations on how to handle these issues.

VI. Conclusion

Intelligent robots can have an important impact on our society in the future and help us to deal with e.g., demographic changes. Equipping the PTR Robot with AI features can support patients and healthcare professionals. This can have a positive influence on work related injuries for healthcare professionals, the recovery success and time of patients. However, success and acceptability of such solutions also dependent on the ethical considerations applied during the development process and later by the robot when interacting with humans. The project outline presented in this paper will investigate how robot companies can become more aware of ethical issues and actively include them in their decision-making process during the development.

Acknowledgment

The project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 825183. The project will be conducted in a collaboration between Washington University in St. Louis (McKelvey School of Engineering, Electrical & Systems Engineering) and Blue Ocean Robotics.

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