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Human-Robot Interaction: Safety Issues

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A B S T R A C T

Human-robot interactions (HRIs) have increasingly become a focal point in research and development, with applications ranging from personal assistants to healthcare companions. Within this landscape, ensuring the safety of individuals engaged in such interactions is of paramount importance. This research investigates how the social credibility of HRIs influences the safety of humans, particularly in scenarios involving robots with limited intelligence or awareness.The interaction between humans and robots in social environments presents unique challenges, as it involves navigating complex social cues, expectations, and norms. When robots possess limited intelligence or awareness, the potential for safety-related issues escalates, posing risks to both the robot and the human participant. These risks encompass physical harm, emotional distress, and damage to property, among others.Understanding the role of social credibility in mitigating these risks is crucial for the development and deployment of safe and effective robotic systems. Social credibility refers to the perceived trustworthiness, competence, and reliability of a robot as a social agent. Factors influencing social credibility may include the robot's appearance, behavior, communication skills, and adherence to social norms.By examining the interplay between social credibility and safety in HRIs, this research aims to uncover underlying mechanisms and identify strategies for enhancing safety outcomes. It adopts an interdisciplinary approach drawing from psychology, human-computer interaction, robotics, and sociology to provide a comprehensive analysis.Empirical investigations utilizing experimental methodologies, surveys, and observational studies offer insights into how variations in social credibility impact safety perceptions and behaviors in human-robot interactions. The findings from these studies contribute to the development of theoretical frameworks and practical guidelines for designing socially credible and safe robotic systems.Ultimately, this research seeks to inform the design, implementation, and regulation of HRIs to ensure that they meet the highest standards of safety and reliability. By addressing the complex interplay between social credibility and safety, it lays the groundwork for fostering trust and acceptance in human-robot interactions across diverse social contexts.

1. Introduction

Artificial intelligence (AI) stands at the forefront of problem-solving technology, revolutionizing automation by empowering machines to act independently. With the advent of new deep learning algorithms in robotics, control systems are becoming increasingly human-independent, ushering in a new era of innovation. The intersection of autonomous robotics and human-computer interaction (HCI) has given rise to a burgeoning field known as Human-Robot Interaction (HRI), capturing the attention of academics and industry professionals alike.

In this rapidly evolving landscape, the functionality of robots is no longer limited to mere task execution; rather, their ability to engage with humans in a manner that is intriguing, entertaining, or practical is becoming increasingly essential. This shift in focus has prompted the exploration of diverse communication models within the realm of HRI, delineated into four distinct categories:

1. **The robot as an instrument:** In this model, the robot serves as a tool or utility, assisting humans in accomplishing specific tasks or objectives efficiently. This utilitarian approach emphasizes the robot's functionality over social interaction.
2. **The robot extending into a cyborg:** Here, the boundaries between human and machine blur as the robot integrates seamlessly into the human user's body or environment. This symbiotic relationship between human and machine opens up new possibilities for enhanced capabilities and functionalities.
3. **The robot as a social companion:** This model highlights the role of the robot as a social entity, capable of engaging with humans in meaningful and interactive ways. Social robots are designed to exhibit human-like qualities, fostering emotional connections and social bonds with users.
4. **The robot as avatar:** In this model, the robot serves as a virtual representation of a human user, facilitating communication and interaction in digital environments. Avatars enable remote presence and teleoperation, bridging geographical distances and facilitating collaborative endeavors.

Amidst this diverse array of communication models, the focus of this research lies in examining the social robot and its credibility in interacting with the social environment. While the allure of social robots lies in their ability to engage with humans in captivating ways, it is imperative to prioritize safety considerations. As robots increasingly integrate into various aspects of human life, ensuring the safety of both humans and robots becomes paramount.

This research endeavors to delve deeper into the complex interplay between social interaction and safety in HRI, shedding light on the challenges and opportunities inherent in this evolving field. By examining the factors influencing the safety of human-robot interactions, this study seeks to contribute to the development of robust and reliable robotic systems that can effectively navigate diverse social environments while prioritizing the well-being of all stakeholders involved.

2. Open Research Question

As social robots become increasingly prevalent in society, it is imperative that they are designed to be user-friendly and easily accessible to individuals from all walks of life. In order to facilitate widespread acceptance and integration into daily life, several key principles must be considered:

1. **Simplicity of Operation:** Social robots should be intuitive and straightforward to operate, requiring minimal technical expertise or training. By prioritizing simplicity, users can interact with the robot effortlessly, without feeling overwhelmed by complex interfaces or commands.
2. **Interesting Behavior:** To capture the interest and engagement of users, social robots should demonstrate compelling and captivating behaviors. Whether it's through expressive gestures, engaging dialogue, or interactive activities, the robot's behavior should be designed to entertain and delight users, fostering positive interactions and rapport.
3. **Enhanced Effectiveness:** By incorporating features that enhance the effectiveness of human-robot interactions, such as prompt task completion and responsive communication, social robots can empower users to accomplish tasks more efficiently and effectively. This increased effectiveness can lead to greater satisfaction and acceptance among users.
4. **Natural Communication:** Given humans' innate social nature, social robots should be capable of natural and fluid communication. This entails understanding and responding to verbal cues, gestures, and social norms in a manner that feels authentic and human-like. By simulating natural conversation and social interaction, the robot can establish a sense of rapport and connection with users.
5. **Social Learning Abilities:** Social robots equipped with social learning capabilities can adapt and evolve based on their interactions with users. By observing and imitating human behavior, the robot can learn new tasks and behaviors, making it easier for users to teach and train the robot to perform specific activities. This flexibility and adaptability enhance the robot's utility and relevance in various contexts, from assisting the elderly with medication reminders to entertaining children with interactive games.
6. **Versatile Application:** Social robots should be versatile in their functionality, capable of performing a wide range of tasks and activities to meet diverse user needs. Whether it's providing assistance in healthcare settings, engaging in educational activities with children, or assisting individuals in their homes, the robot should be adaptable and responsive to different environments and requirements.

In essence, the successful integration of social robots into society hinges on their ability to embody these principles of simplicity, engagement, effectiveness, natural communication, social learning, and versatility. By prioritizing these factors in the design and implementation of social robots, researchers and engineers can pave the way for a future where human-robot interactions are seamless, enriching, and empowering for all involved.

The most crucial issue to consider when dealing with human-robot interactions is the safety of both humans and robots. Robots can be extremely powerful and pose a threat to humans. It is vital to pay attention to this issue. Before you can solve the above problems, you must first figure out what is creating it. To correct this, we must first define the risk, then who it affects, what repercussions it will have, and which elements have the most impact on the safety. Mechanical faults, human errors, and adverse environmental conditions can all be sources of hazard. The person who controls a robot is in jeopardy. If the robot behaves strangely, the operator must deal with it. When a robot is really not working properly, there seems to be a significant chance that the operator gets hurt. Pinch and impact injuries are the two types of injuries that might occur. A pinch injury happens when a robot catches a user between itself and an object, whereas a contact injury occurs when the robot and the human crash. The three sorts of outcomes include minor repercussions with no lost work time, lost work-time injuries, and deadly injuries. Injury from a pinch appears to become riskier than injury from an impact (Vasconez, et al., 2019).

The safety of both humans and robots in human-robot interactions (HRIs) is indeed paramount, requiring careful consideration and proactive measures to mitigate potential risks and hazards. To effectively address safety concerns in HRIs, it is essential to understand the underlying factors contributing to these risks and their implications. Here are some key aspects to consider when expanding on the crucial issue of safety in HRIs:

1. **Identifying Sources of Hazard:** Understanding the various sources of hazard is fundamental to assessing and managing risks in HRIs. Mechanical faults, such as malfunctions in robot components or hardware failures, pose a significant threat to safety. Likewise, human errors, whether in programming, operation, or maintenance, can lead to hazardous situations. Additionally, adverse environmental conditions, such as uneven terrain or inclement weather, can exacerbate safety risks in HRIs.
2. **Assessing Risk Impact:** It is essential to evaluate the potential consequences of safety hazards in HRIs to determine their severity and impact. Risks may vary in their repercussions, ranging from minor injuries with no lost work time to more serious outcomes, including lost work-time injuries and even fatalities. Understanding the potential consequences of safety hazards is crucial for prioritizing risk mitigation strategies and allocating resources effectively.
3. **Analyzing Injury Types:** Pinch and impact injuries are two common types of injuries that may occur in HRIs. A pinch injury occurs when a user becomes caught between the robot and an object, while an impact injury results from a collision between the robot and a human. Each

type of injury presents unique challenges and requires tailored approaches to prevention and mitigation. By analyzing the characteristics and causes of these injuries, researchers and engineers can develop targeted interventions to enhance safety in HRIs.

4. **Considering Operator Safety:** The safety of individuals who control or interact with robots is of utmost importance in HRIs. Operators may be at risk of injury if the robot malfunctions or behaves unexpectedly. Therefore, it is essential to provide adequate training, support, and safety protocols for operators to minimize the likelihood of accidents and injuries during robot operation.

5. **Implementing Safety Measures:** Proactive measures should be implemented to mitigate safety risks in HRIs effectively. This may include incorporating safety features and fail-safe mechanisms into robot design, implementing rigorous testing and validation procedures, and establishing guidelines for safe operation and interaction with robots. Moreover, ongoing monitoring and evaluation are essential to identify and address emerging safety concerns in HRIs.

By addressing these key aspects and taking a comprehensive approach to safety in HRIs, researchers and practitioners can work towards creating safer environments for humans and robots to interact effectively and collaboratively. Through continuous innovation and improvement, the field of human-robot interaction can advance towards a future where safety is prioritized, and the potential benefits of robotics are realized responsibly.

3. Existing and related work

A number of safety features, including as collision avoidance, reducing force of impact to a sensible level in the case of an accident, human-aware navigational strategies, an5d techniques for safe navigation in dynamic settings, are now being employed to assure safety in human-robot contact. Implementing dependability strategies at all levels of robotic solution development is one strategy for building mutual trust and collaborative robots. The design and implementation of arobotic system based on ISO and Specifications requirements that must be met, as well as the robot's capacity to work in close proximity to mankind without difficulty, results in reliability (Hentout, et al., 2019).

Until date, the most of studies have focused on navigation and planning safety in crucial situations, as well as obstacle detection safety. As a reason, despite the fact that earlier research has identified a diversity of techniques to producing safe robots, the central emphasis is on how to enhance human perception of robots. Human perception, according to previous studies, is a significant aspect in use or acceptability of cobots. Human will not welcome an untrustworthy robot in such a setting where the consequences of losing can be terrible, thus human perception is especially crucial whenever a human-robot collaboration work is performed in tough and dynamic environments in a time-critical way (Caleb-Solly, et al., 2018).

Pepper is a humanoid robot that is 1.2 meters tall and can move its limbs. When older adults interact with Pepper, they run the risk of falling or colliding with other people. Physical engagement between a humanoid robot and humans may result in potentially dangerous physical touch. Pepper has interactive characteristics like speaking to elders to get them involved and extending its hands to get them to touch it. Pepper's application also includes language software that imitates a six-year-old child, giving the sense of talking with a kid. As a result, these are some of the factors that encourage older individuals to approach and touch Pepper. Even in clinical conversations with elderly persons utilizing Pepper, it was noticed that they frequently held and hugged Pepper's hand or head in the middle or at the end of their discussion. For Pepper's future generation, a self-propelling capability is being researched. It is feasible that an older person will approaches Pepper, resulting in an accident or a fall, despite the fact that this has not been witnessed.

Safety can be improved by adding machine learning approaches into action robotic capabilities and incorporating environmental restricti analytical ones (Lasota, et al., 2017).

4. Research Approach Personal Investment

Different safety elements should be incorporated depending on the application situation and the operating environment in which the envisioned robot is planned to work. Beginning with the design process, the basic standards should be enforced, considering the needs of the application that the intended robot will be engaging with. Following this, a complete and precise architecture should be carefully built, taking into account both software and hardware. The system's early dependability is defined at this stage. To begin, a careful selection of hardware platforms that will enable sophisticated software capabilities should be established. Force/torque sensing in each joint is critical in arm manipulators to provide compliance manipulation control. Hollow shaft motors and gearboxes are necessary to hide cables inside the robot'sembodiment, preventing unexpected grounding that could result in hazardous situations during HRI (Hentout, et al., 2019).

Pepper's upper limbs are connected to the computer, and it will stop moving if a person encounters the rotational radius of its upper limbs. Anyone in close proximity to Pepper can press an emergency button on Pepper's main body if somehow the computer fails. It has safety mechanisms, such as a soft fabric that protects its arm. Moreover, Pepper's fingers have a highly brittle structure. As a result, it contains a safety function that reduces the chance of physical harm to people even if an older adult touch or holds Pepper's arms. The image of Pepper in current safety features is shown in Figure 1.

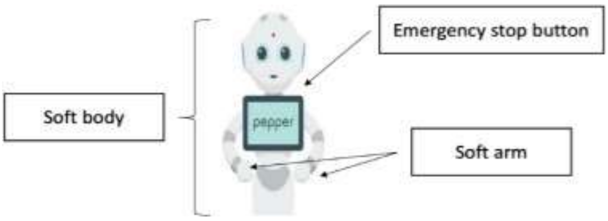

Figure 1: existing appearance of a Pepper Robot

Measures such as "widening the installation area with the ground" and "widening the distance between the wheels" are proposed to make Pepper less likely to fall as a safety safeguard against the user being dragged down when Pepper falls. Installing pressure sensors on the surface of Pepper's body to make it stop by sensing if someone has gotten caught in its arms or joints is proposed as a countermeasure to in dividuals getting entangled in its arms or joints. In order to protect Pepper's fingers from slamming into people's eyes, goggles are also suggested. The reactions of older persons to Pepper's functions are unexpected. As a result, ways to ensure its safety in advance and to improve the robots' safety and properties must be clarified. The advantages of bringing in support robots like Pepper into aged medical and nursing care environments are clear (Villani, et al., 2018).

As a result, it is vital to participate in robot development while taking into account both the risks and the rewards.

5. Personal Investment

In the realm of human-robot interaction (HRI), the concept of personal investment extends beyond financial considerations to encompass the well-being and safety of individuals engaging with these machines. As society witnesses an increasing integration of robots into various aspects of daily life, particularly in social environments, the imperative for ensuring safety becomes paramount. While professionals in robotics design and engineering may possess the technical expertise to address safety concerns, the majority of individuals interacting with social robots may lack such specialized knowledge. This knowledge gap underscores the need for broader awareness and proactive measures to safeguard against potential dangers stemming from robot malfunction or poor performance.

At the heart of personal investment in HRI lies a fundamental concern for the safety and well-being of both humans and robots. This entails recognizing and addressing the inherent risks associated with human-robot interactions, ranging from mechanical failures to unforeseen errors in programming or operation. Individuals engaging with social robots, whether in domestic settings, healthcare facilities, or public spaces, must be equipped with the knowledge and resources to navigate these interactions safely.

One crucial aspect of personal investment in HRI is the cultivation of a culture of safety and responsibility. Just as individuals are taught to exercise caution when operating machinery or driving vehicles, they should also receive guidance on how to interact safely with social robots. Educational initiatives, public awareness campaigns, and standardized safety protocols can all play a role in promoting a culture of safety in HRI.

Moreover, personal investment in HRI extends to the design and development of social robots themselves. Engineers and designers must prioritize safety considerations throughout the entire lifecycle of a robot, from concept and prototyping to deployment and maintenance. This includes implementing robust safety features, conducting thorough risk assessments, and continuously monitoring and improving the safety performance of robots in real-world settings.

Finding ways to keep both people and robots safe represents a significant opportunity for innovation and collaboration across disciplines. Researchers, engineers, policymakers, and end-users must work together to identify and address safety challenges in HRI, leveraging advancements in technology, psychology, and regulatory frameworks.

Ultimately, personal investment in HRI is not just about mitigating risks; it is also about unlocking the full potential of social robots to enhance human well-being and quality of life. By prioritizing safety and responsible engagement with these machines, we can pave the way for a future where humans and robots coexist harmoniously, enriching each other's lives in meaningful and impactful ways.

6. Conclusion

In conclusion, this research delves into the intricate dynamics of human-robot interactions (HRIs) with a focus on safety considerations, particularly in contexts where robots possess limited intelligence or awareness. The safety of both humans and robots is paramount in these interactions due to the potential risks and consequences associated with mechanical faults, human errors, and adverse environmental conditions.

By examining the role of social credibility in influencing safety perceptions and behaviors, this study contributes to our understanding of how to foster safe and reliable HRIs in diverse social environments. It underscores the importance of addressing safety concerns from the design phase through implementation, considering factors such as collision avoidance, force reduction, and human-aware navigational strategies.

Furthermore, the research highlights the necessity of incorporating machine learning approaches and environmental restrictions to enhance safety measures in robotic systems. By identifying potential risks and proposing countermeasures, such as widening installation areas and installing pressure sensors, the study emphasizes proactive approaches to ensuring safety in HRI scenarios.

Ultimately, the findings underscore the importance of balancing the benefits of social robots with the need to mitigate potential risks, thus advocating for a cautious and proactive approach to human-robot interaction design and implementation. This research contributes to advancing the field by providing insights and recommendations for creating socially credible and safe robotic systems that can effectively interact with humans in various social environments.

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