Optimal Operational Safety Metrics for Human-Robot Interaction: A Comprehensive Overview.

Mercy Okebiorun

Abstract

Human-robot interaction, or HRI, has grown in importance across a wide range of industries, including manufacturing, healthcare, agriculture, and logistics. Ensuring operational safety metrics is essential to lowering potential risks and guaranteeing a safe, secure, and effective interaction between humans and robots in daily life. With an emphasis on the most pertinent and useful metrics to be applied, this review aims to give a thorough overview of the state of HRI safety metrics as of right now.

Keywords: HRI, safety, affective computing, research.

Introduction

It is indisputable that the integration of robots into human workspaces has increased output, effectiveness, and standard. However, there are significant worries that this increased cooperation could jeopardize public safety by increasing the possibility of accidents, malfunctions, misinterpretations, and property or equipment damage. Identifying possible hazards and devising a mitigation strategy require the development of optimal operational safety metrics.

Latest trends in HRI safety.

1. Advanced Sensing Technologies:
- The integration of LIDAR and cameras into robotics has resulted in a notable expansion within the HRI community. This is because their complementary roles in enabling robot vision are evident. Its value in environmental mapping and human detection cannot be questioned.
- Ultrasonic sensors: Integrated into robotic systems to detect and avoid obstacles, ultrasonic sensors work in tandem with visual sensors. When an obstacle is detected, it sends signals to a robot control system instructing it to take corrective action. This makes the movement of the robot efficient.

2. Algorithms for Machine Learning:
- Predictive Algorithms: These modeling techniques make use of mathematical and statistical methods to forecast behavior in the future based on research and historical patterns. These algorithms facilitate the robot's ability to anticipate human behavior and make necessary adjustments.
- Reinforcement learning and Computer Vision: Robots can learn interactions and adjust safety precautions thanks to reinforcement learning and computer vision, which also improve their capacity to comprehend and react to human gestures and actions.

Methodologies for Optimal Operational Safety Metrics for Human-Robot Interaction:

Enhancing HRI through force sensing: A vital element of HRI, force sensing allows robots to recognize and react to human forces and intentions. The efficacy, efficiency, and safety of human-robot cooperation could all be enhanced by this technology. Based on studies conducted by the Tokyo University of Agriculture and Technology's Mechanical Systems Engineering Department. It has been shown that force sensors make it possible to automate a wide range of tasks that were previously carried out using only human touch perception. Two experiments were conducted as part of the study: touch gesture acquisition and emotion transfer on a robot arm with sensors. These gestures were classified with a higher probability than chance using machine learning. Real touch enhanced the robot's impression. The study is in contrast to an experiment conducted by Matthew Scheutz, which examined the effect of touch on human-robot trust by creating a movie depicting robots interacting with humans. According to the study, scientists should look into touch between humans and robots as well as touch between robots and humans.

Affective computing techniques: These make use of cognitive computing principles to give machines the ability to replicate human decision-making and to model human thought processes**.** This enables robots to comprehend and sympathize with their users more fully. Drawing from a research study by Geoffrey Gaudi, Bill Kapralos, K. C. Collins, and Alvaro Queved titled Affective Computing: An Introduction to the Detection, Measurement, and Current Applications, this journal covers the fundamentals and present status of affective computing while tackling various issues. The misunderstanding of emotion's definition, source, and formation is the first obstacle. Another problem is the often ineffectiveness of current models when it comes to categorizing emotion and affective response. There are also differing opinions about how to employ certain tools, like neural network training and the interpretation of facial data. Although having multiple sources of input improves detection accuracy, it also raises expenses and necessitates more data processing.

Affective technology development and use raise ethical questions, especially in regards to privacy invasion and monitoring. Since some research has been done on people without disabilities to develop therapies for the disabled, the use of artificial intelligence and its datasets presents similar concerns. The application of natural language processing (NLP) techniques has to be expanded, particularly in the cultural sphere, since word choice and meaning are socially, culturally, contextually, and individually determined.

The Ekman model, which is based on various psychological theories of emotion, is used in facial recognition. The consequences of developing affective systems, however, remain unclear due to the unreliability of extracted data and possible bias stemming from researchers' cultural expectations. A bigger problem with privacy rights is who owns the data on our emotional reactions if they are recorded.

Notwithstanding these obstacles, affective computing presents a plethora of fascinating opportunities that have the potential to enhance our lives, including chatbots, games, therapists, and companions. It is imperative that affective computing be continued despite possible misuses.

Interface for collaborative robotic assembly tasks:
A study conducted by Papadopoulos et al., 2017,introduces an advanced human-robot interaction (HRI) interface that enables teaching new assembly tasks to collaborative robotic systems. The interface uses advanced perception and simulation technologies to provide the necessary tools for a non-expert user to teach a robot a new assembly task quickly. An RGBD camera is used to demonstrate the task, and the system extracts necessary information for the assembly to be simulated and performed by the robot, while the user guides the process. The HRI interface is integrated with the ROS framework and built as a web application that can be operated through portable devices like tablets.

The research focuses on the functionality of the HRI system for teaching robotic assembly tasks, addressing the challenges of reducing time and resources needed to teach robots. The proposed system is simple enough for a non-expert user to demonstrate new assembly tasks while still enabling the user to supervise the assembly execution. The interface is interconnected with various components of the complete system, including the Perception module, which captures RGB and Depth data in real time, and the Key-frame Extraction module, which calculates the trajectory of parts using key-frames from the demonstration.

The main contributions of the proposed system include a user-friendly, intuitive interface, a portable, ROS integrated web-based interface compatible with most computer systems, and assembly simulation capabilities. The paper extends the work presented at the SPECOM2017 conference, including experiments with more test subjects, additional questionnaires and metrics, additional information about the interface and its operation, updated screenshots, and new figures.

Conclusion

Human-robot interaction (HRI) has become increasingly important in various industries, including manufacturing, healthcare, agriculture, and logistics. Optimal operational safety metrics are crucial for reducing risks and ensuring a safe, secure, and effective interaction between humans and robots. Recent trends in HRI safety include advanced sensing technologies like LIDAR and cameras, ultrasonic sensors, predictive algorithms, user-centric design, force sensing, and affective computing techniques.

Ultrasonic sensors work in conjunction with visual sensors to detect and avoid obstacles, making robot movement efficient. Predictive algorithms use mathematical and statistical methods to predict future behavior based on research and historical patterns, allowing robots to anticipate human behavior and make necessary adjustments. Ergonomic design ensures human safety and comfort, while intuitive interfaces encourage user-friendliness and reduce human mistakes. Feedback mechanisms allow users to offer suggestions for improving performance and safety.

Force sensing enhances HRI by allowing robots to recognize and react to human forces and intentions, improving efficiency and safety. Affective computing techniques use cognitive computing principles to replicate human decision-making and model thought processes, enabling robots to understand and sympathize with their users more fully.

A study by Christos et al. introduced an advanced human-robot interaction (HRI) interface that enables teaching new assembly tasks to collaborative robotic systems. The interface uses advanced perception and simulation technologies to provide necessary tools for a non-expert user to teach a robot a new assembly task quickly. The interface is integrated with the ROS framework and built as a web application that can be operated through portable devices like tablets.

This study is an invaluable resource for researchers and practitioners as it provides a thorough assessment of the current status of HRI safety and suggests future paths for further research.

References

Hayashi, A.; Rincon-Ardila,L.K.;Venture, G. Improving HRI with Force sensing. Machines 2022,10,15. http://doi.org/10.3390/machines10010015

Papadopoulos et al., 2017: An Advanced Human-Robot Interaction Interface for collaborative robotic assembly tasks. International journal of embedded and real time communication systems, volume 9, 2018. http://dx.doi.org/10.1007/978-3-319-66471-2_20

Geoffrey.; Bill.; K.C, Alvaro.; Affective Computing: An introduction to the detection, measurement and current applications.http://dx.doi.org/10.1007/978-3-030-80571-5_3