An investigation on the impact of human-robot interactions during an autonomous obstacle avoidance task

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Abstract

The purpose of this research is to investigate how an interaction between humans and robots influences a safety of an autonomous obstacle avoidance task. The research collected and analyzed data from surveys and interviews using a combination of quantitative and qualitative methodologies. The findings contributed to our understanding of a complex interplay between a human-robot interaction, a perception, and a robot navigation safety. Based on these findings, the study proposed a number of recommendations for improving both physical and psychological safety aspects of an autonomous robot navigation.

Keywords: Human-robot interaction, HRI, autonomous obstacle avoidance, navigation safety

1. Introduction

Autonomous robots are becoming an integral part of diverse human environments due to the advancements of robotic technologies from personal healthcare [1] to automated manufacturing fields [2], [3]. The progression is expected to lead to a future in which both humans and robots coexist and interact on a regular basis [4], [5]. However, the integration of autonomous robots into human environments is not without significant challenges, particularly when it comes to ensure safety during autonomous obstacle avoidance tasks [6], [7]. Autonomous obstacle avoidance [8] and human following [9] is a critical feature for any autonomous robot operating in a human-populated environment [10]. It is a capability that allows a robot to navigate through an environment avoiding static and dynamic obstacles, including humans. A robot which can precisely avoid obstacles is considered safe [11]. Understanding and addressing various aspects of safety require a comprehensive exploration of the relationship between humans and robots [12], [13]. This involves indulging into the complex dynamics of human-robot interaction (HRI), which encompasses the objective behavior of the robot, subjective experiences and perceptions of the human [14], [15].

The objective of this research is to provide an in-depth examination of the relationship between humans and robots, focusing on its impact on the safety of autonomous obstacle avoidance. Specifically, the research will investigate how humans interact with robots that are capable of autonomous navigation. The investigation will contribute to a deeper understanding of this critical aspect of autonomous robotics, providing insights that could help improve the design and operation of future autonomous robots. It will also address gaps in the existing body of knowledge, particularly in the intersection of autonomous navigation, HRI, and perceived safety [16]. Surveys and interviews were conducted in a group of people, who had experience with robotic environments. The inferences obtained through these surveys and interviews were used to conclude about the current status of HRI in various fields [17].

2. Methodology

The methodology outlines the research approaches that were utilized to investigate the relationship between HRI and the safety of autonomous obstacle avoidance. The research began with a comprehensive review of existing literature from databases, journals, and conference proceedings related to HRI, robotic safety, and autonomous obstacle avoidance. Following the comprehensive literature review, the research focused on the development of an experimental setup, which consisted of a robot equipped with a capacity for autonomous navigation and obstacle avoidance. A restaurant delivering food to customers using a mobile robot (shown in Fig. 1(a) was selected for the survey. The robot can move to assigned tables and deliver food as shown in Fig. 1(b).

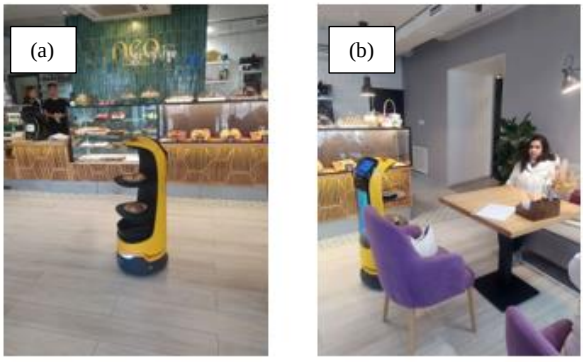

Fig. 1 Robot navigation (a) A food delivery robot (b) The robot delivering food to customers

The robot avoided collision with static and dynamic obstacles using IR sensors fixed on the base of the robot. Fig. 2 depicts the stages of a food delivery using the mobile robot. Fig. 2 represents the robot waiting for the food delivery near the restaurant kitchen. Fig. 2(a) and (b) represent a motion of the robot towards the assigned table and destination table respectively. A customer receiving the food items are shown in Fig. 2(d).

To obtain a human-centered perspective on the safety and comfort of autonomous robots, surveys and semi-structured interviews were conducted with individuals who had interacted with the robot. Questions were designed to explore various phases of human-robot interaction, including social acceptability, perceived safety, and trust in the robot's autonomous decision-making capabilities. The customers and employees working in the restaurant were participated in the survey. The gathered data were subjected to rigorous analyses using suitable statistical techniques. This critical process of data analysis allowed the transformation of raw data into meaningful information, thereby offering both quantitative and qualitative insights into the correlation between HRI and the safety of autonomous obstacle avoidance.

Fig. 2 Different phases of the robot work: (a) Robot waiting for collecting food items (b) Moving to towards a destination table (c) Robot reached the destination table (d) A customer taking the food item from the robot

The final step in the methodology involved the validation of the findings. This was done through peer-reviews and expert consultations, ensuring the research conclusions were robust, reliable, and could stand up to scrutiny. This step served as a quality check and ensured that the research had been conducted in a methodologically sound manner. Further, it also provided an opportunity for receiving recommendations for future studies, thereby adding to the overall value and impact of the research. This methodological approach aimed to provide a comprehensive, multi-dimensional understanding of the research topic, combining the strengths of both empirical and qualitative research methods.

3. Results/findings

In this section, we present and analyze the results gathered from our research and the insights obtained from the HRI studies. we conducted surveys and interviews with participants after they observed or interacted with the robot. A total of 60 participants attended the survey and expressed their opinions and suggestions regarding the coexisting of humans and robots inside a restaurant environment. The qualitative data suggested a generally positive perception of safety, comfort, and trust in the robot's autonomous capabilities. Approximately 90% of the participants reported that they felt safe with the robot's movements and obstacle avoidance capabilities. Interestingly, a correlation was observed between the

robot's behavior and participant responses. Smoother and slower robot movements were associated with increased comfort and trust ratings from the participants. About 80% of the participants conveyed that the robot food delivery was faster compared to human food delivery services. However, some of the participants are concerned about the precision of delivery and quoted about interaction difficulties they faced during food order updating.

The perception of risk and social acceptability associated with the autonomous robot were also included in the survey. We interpreted that in a populated environment, participants perceived the robot as less risky compared to a controlled environment, contrary to our expectations. This might be attributed to the social dynamics of a populated setting, where humans provide an additional layer of unpredictability that makes the robot's autonomous capabilities more evident and appreciated. The social acceptability of the robot was rated highly by 82% of participants, signifying the successful integration of social robotics principles in its design and operation. However, 27% of the customers preferred contactless delivery. 70% of the participants considered robot usage inside a restaurant as an eco-friendly option. 20% of the participants chose human workers in place of autonomous rover delivery due to safety concerns. Most participants concerned about the robot malfunctioning, and navigational errors.

4. Discussion

The study was designed to investigate the relationship between HRI and the safety of autonomous obstacle avoidance, contributing to the growing body of knowledge in this field. The multi-dimensional methodological approach, combining both empirical and qualitative research methods, was integral in producing a comprehensive understanding of the research topic. The survey results regarding autonomous navigation and obstacle avoidance revealed that the robot was successful in navigating the environments and avoiding obstacles with a high success rate.

Results from the HRI revealed a generally positive perception of the robot's autonomous abilities, showing trust in the robot's decision-making and overall satisfaction with their interaction. These findings provided valuable insights into the subjective aspects of robot safety, complementing the quantitative data obtained. Risk perception and social acceptability were also significant factors in our study. Results suggested that participants perceived the autonomous robot as safe and socially acceptable, even in densely populated environments.

When performing HRI activities, robots must be equipped with adaptive abilities to prevent accidents and task incompletions. There are a lot of static and dynamic obstacles present in a restaurant setting. In order to prevent collisions when moving from the food pickup location to the destination table, the robot needs to be employed with an effective collision avoidance approach. By utilizing proper sensors and controllers, the robot can steer clear of obstructions and prevent crashes during the motions. Reserving separate paths for robots can minimize chances of collisions with obstacles. To help users comprehend how the robot is moving, the robot can also show path details on a screen or verbally during its motion.

The study's findings also had several theoretical implications. They reinforced the theories of autonomy, social robotics, proxemics, risk perception, and planned behavior [15]. The robot's autonomous performance aligned well with the theory of autonomy in robotics. The feedback from participants suggested that social robotics theories were applicable in real-world environments, reinforcing the necessity of developing robots that respect human social norms.

5. Conclusion

In conclusion, the research undertaken successfully addressed the primary goals of investigating the relationship between HRI and the safety of autonomous obstacle avoidance. The investigation revealed that the interaction between humans and robots is multi-faceted. It emphasized that the concept of safety in autonomous obstacle avoidance is not limited to the physical ability of the robot to navigate without causing collisions or accidents. It also heavily depends on the subjective feelings of safety, comfort, and trust experienced by the humans who interact with or are in the vicinity of these robots. Therefore, the importance of considering both objective and subjective factors when evaluating the safety of autonomous robots in environments shared with humans was strongly underscored. This research also pointed towards potential areas for future study, demonstrating that the quest for knowledge in this domain is far from exhausted. For instance, it suggested the need for further exploration into how different design elements and behavioral parameters of the robot might influence human perception and interaction. This could include aspects such as the robot's size, color, speed, motion patterns, and communication methods. Research into these directions could yield interesting results that might further refine the approach to designing and deploying autonomous robots in human environments.

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