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論 文 題 目	Learning Proxemics for Identifying Human Private Space in Human-Robot Social Interaction
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論文の内容の要旨

Mobile robots are tended to provide more and more service in the shared environment with humans. Human-Robot interaction (HRI) is a critical component to allow a robot to operate with humans in the proper direction. To design the robot system to operate with humans natural and acceptable, robots should have the ability to perceive, understand and act in a manner that conforms to the social convention like move to the right side of corridor or keep human personal or private space during an interaction , which is the fundamental key to human-robot symbiosis.
Notably for a navigation task that robots should move to provide the services in a different location, robots should maneuver themselves without harm or damage the surrounding environment which includes humans. Although robots can generate safe navigation, sometimes humans feel not safe with the robot motion. The main reason come from the lacking of trust to the technology which occurs from the unfamiliar of the robot's appearance or less experience with the robot. Therefore, the robot navigation task should not consider only safe behavior but should increase attention to generate social behavior which enables the robot to behave more naturally and acceptable to operate with humans.

For human-human interaction, the personal area is the one instance social convention that humans consider when interact with others. This interaction area of humans consists of two areas. First is the quality interaction area, where humans can be engaged in high-quality interactions with others. Second is the area of privacy where humans do not want to interfere with others speech or action. The size of these two areas usually depends on various social information such as their motion, personal traits, and acquaintanceship.

The same concept applies to the case of human-robot interaction, especially when the robot is required to exhibit a certain level of social competence. Therefore, the challenge is how to formalize or estimate the personal area from various human social information.

In this dissertation, we proposed a new robot navigation strategy to socially interact with humans reflecting upon the social information between the robot and each person. The proposed model aims to enable the robot to estimate or delineate the personal area of each person by using their social information and it is possible to update this personal area based on their feedback. The results of our method enable the robot to estimate the personal area and update it until it appropriates to each person. This adaptive personal area assists the path planner to generate the path that does not intrude into the area of privacy but keeps distance to give a quality interaction. The proposed model uses an asymmetric Gaussian function to estimate each personal area where a fuzzy inference system is used to design the required parameters. The fuzzy membership functions are optimized to give the robot the ability to navigate autonomously in the quality interaction area using a reinforcement learning algorithm. It was verified through simulations and experiments with a real robot that the proposed strategy can generate a suitable personal area of each person that allowing the robot to maintain the quality of interaction with each person while keeping their private personal distance.

Keywords: Proxemics, Social Interaction, Social Force Model, Fuzzy Inference System, Reinforcement Learning

論文審査の結果の要旨

This dissertation addresses the problem of human-robot proxemics for autonomous mobile robots toward realizing socially competent navigation by integrating a fuzzy inference system and a reinforcement learning method. The author’s main contribution is two-fold: First, he proposed an efficient computational framework that enables a robot to select proper human-robot distance and pose parameters adapting to the user’s social cues; second, he implemented a cost-based trajectory planner for maximizing the quality of interaction while minimizing the unacceptable degree, allowing the robot to navigate in a space populated with varying numbers of interacting people in alignment with their sociocultural traits. The effectiveness of the proposed approach was verified through extensive computer simulations and experimental validation with an off-the-shelf humanoid robot. Overall, this research opens doors to impactful change in personalized and adaptive social human-robot interaction.

Specifically, the author proposed a new social force model based on a fuzzy inference system to autonomously estimate the user's social space from his/her personal parameters. He thoroughly tested and compared a variety of reinforcement learning algorithms, in terms of learning time, optimal values, and exploration rate. The proposed self-learning proxemics model has been published in the Elsevier Journal of Social Robotics, one of the prestigious journals in the field of Human-Robot Interaction. In contrast to most of existing approaches that rely on predetermined interaction parameters or their modification with embedded heuristic rules, this work explores the benefits of using machine learning approaches that would learn and continuously improve from a long-term history of social encounters. Social robots endowed with the capability of proxemics can enter into and engage in social encounters with a variety of people in different settings. The proposed framework can be used in a wide variety of applications, where the user personality traits should be considered a high priority during human-robot interaction. This is an excellent dissertation and we approve awarding a doctoral degree to PATOMPAK Pakpoom.