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Dissertation Defense

Doctor of Philosophy in Information Science

"**A Bidirectional Communication Framework for Task Goal Alignment in Human-Robot Interaction**" by **Lesong Jia**

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Abstract:
As motion planning and control advance, robots are becoming increasingly capable of performing a wide range of tasks. However, effective human–robot communication that ensures task goal alignment before execution remains challenging for integrating robots into everyday life. This dissertation develops a user-centered, bidirectional communication framework that enables robots to interpret users' natural instructions while keeping users aware of the robot's understanding and planned actions. The framework comprises three interconnected components: initial context-building communication, through which the robot guides users to introduce the home environment, relevant objects, and preferences to establish shared understanding; multimodal instruction understanding, which interprets users' speech, gaze, and gesture during task instructions; and interactive feedback communication, in which the robot clarifies ambiguities and provides explanations. To develop this framework, this dissertation begins with semi-structured interviews and focus groups with target users, together with domain expert discussions, to understand how users give instructions to robots and how robots should convey information. Building on this foundation, this dissertation proceeds in two complementary directions. The first focuses on human-to-robot communication. Users' natural multimodal behaviors during instruction delivery were collected and analyzed to inform the development of a large language model-based instruction-understanding model for improving robots' recognition and interpretation of user intent. The second examines robot-to-human communication. Quantitative user studies were conducted to evaluate how robots should guide users through initial room tours for context building and provide feedback to clarify task goals, communicate their understanding, and explain planned actions before execution. The findings establish design guidelines for context-building and feedback interfaces that enhance task effectiveness, trust, and user experience. Together, these studies support more fluent, transparent, and trustworthy human–robot collaboration.