An intelligent service system with multiple robots*

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Abstract

This document describes an on-going multi-robot project, an intelligent bartender-waiter robot system in which a team of different robots serves people in a bar. In this system, KeJia robot plays the role of bartender who recognizes and grasps the drink by following the order of people and gives it to a TurtleBot, several TurtleBots deliver drinks to people as waiters. By developing this system, we studied the coordination of multiple different robots, i.e. the ability of dealing with multiple heterogeneous robot, the interaction between humans with a team of robots and the intelligent decision system for task allocation. The long aim of this project is developing a highly intelligent cooperative multi-robot system which can operate in a variety of complex applications at high success rates.

1 Introduction

In modern society, the coordination among people has been becoming more and more close, one has to work with others to finish tasks. For example, a large surgical operation needs the coordination of surgeon, anesthetist and nurse. This raises the problem of perception, reasoning and the capability of physical coordination of team members in an unpredictable environment. Team members must make decisions and take actions sometimes with very limited knowledge about the intention of others.

We are developing an intentionally cooperative system, that is KeJia-TurtleBot system, in which team members vary in their sensors and effector capabilities. Each robot in KeJia-TurtleBot system has knowledge of the presence of other robots and intentionally cooperates with others. To accomplish the bartender-waiter task, they work together based on their observations, states, individual capabilities of teammates.

The research on the coordination of multiple mobile robots includes many aspects, such as control architecture, communication among robots, task allocation and learning. In the next section, we detail the control architecture of KeJia-TurtleBot system. The internal interaction among team members and external interaction with surrounding environments are stated in section 2.1. Some fundamental modules are stated in section 3.

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2 Overview of the system

The control architecture has a direct impact on the group behavior and the interaction of robots in a multi-robot system. Our KeJia-TurtleBot system adopts the hybrid control architectures. This architecture takes advantage of the robustness of distributed local control in low level and the benefit of global plans efficiently influencing the action of team members in high level. The architecture of our KeJia-Turtelbot system for bartender-waiter application is shown in Fig.1.

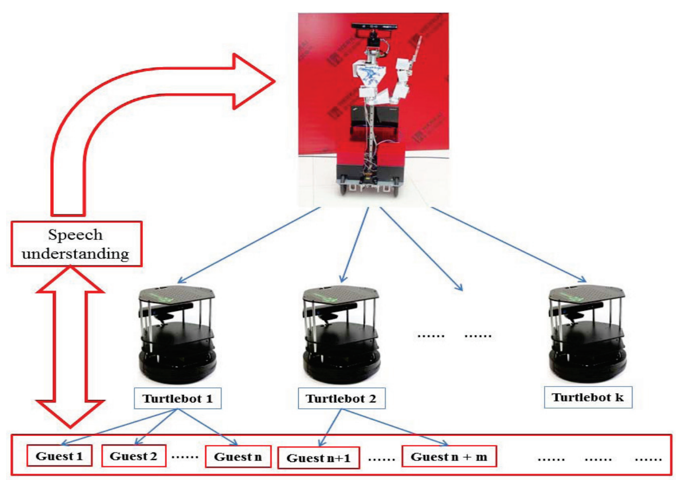

Figure 1: The architecture of KeJia-Turtelbot system for bartender-waiter application.

2.1 Situatedness of KeJia-TurtleBot system

Situated robotics refers to a robot which is embedded in a dynamically changing environment. Situatedness refers to the interaction between a complex, challenging environment with behaviors of single- and multi-robot system who is being embodied in it. The level of situatedness, that is the complexity of the environment and application, determines the complexity of robot control. For bartender-waiter application, the situatedness for this heterogeneous multi-robot systems includes the interaction with humans, the coordination between KeJia and TurtleBots and the coordination among TurtleBots .

The human-robot interaction

Designing service robots capable of safely and effectively interacting with humans is still a challenging problem in robotics. First of all, it should has intuitive interaction operations so that laymen can easily control the robots and understand their intentions. Obviously, speech is the direct and primary interaction way of humans for communicating complex statements. Section 3 gives the details about the speech processing in KeJia-TurtleBot system.

The coordination between KeJia and TurtleBots

In KeJia-TurtleBot system, several general-purpose fundamental modules have been implemented in KeJia, such as natural language processing[Chen *et al.*, 2009], hierarchical task planning and knowledge acquisition[Chen *et al.*, 2010][Chen *et al.*, 2012]. In the bartender-waiter application, the KeJia robot serves as a bartender who receives the voice order from a guest. It recognizes the object and confirms the position of it. Then it grasps the object and gives it to a TurtleBot by its mechanical arm. In this bartender-waiter system, each member broadcasts its own position to the others. So the TurtleBot who is capable of implementing the task at the minimal cost is called to deliver the drink to the guest. It is reasonable that the cost of a delivery task is computed by the distance among the KeJia, TurtleBots and the guest.

The coordination among TurtleBots

There are many people and several waiters in a bar. While several TurtleBot-waiters are moving in the same room, since the position of every member is known to all, they avoid bumping against one another by considering other teammates as obstacles.

3 The support of low level behaviors

In KeJia-TurtleBot system, each robot has some basic behaviors such as navigation, mobile manipulation. These basic behaviors are combined in various ways to yield more complex social behaviors, This section briefly describes some fundamental functions which have been implemented in KeJia-TurtleBot system and support the group behaviors of system. For more information, the reader is referred to the team description paper of WrightEagle@Home for the competition RoboCup@Home 2013.

Dialogue Understanding

The Human-Robot Dialogue module provides the interface for communication between users and the robot. The Speech Application Programming Interface (SAPI) developed by Microsoft is used for speech recognition and synthesis. Fig. 2 shows our implementation (i.e., infinite state machine) of managing a simple human-robot dialogue in which the user tells the robot facts that he/she has observed or tasks, and the robot asks for more information if needed.

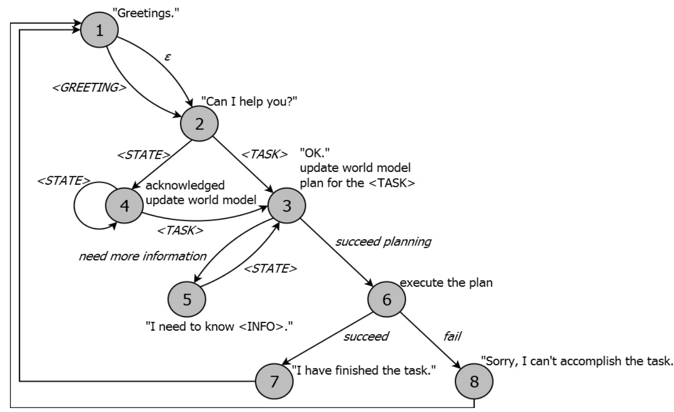

Figure 2: The finite state machine for a simple human-robot dialogue.

Visual Perception

We propose an automatic object modeling pipeline combining point cloud segmentation and the GrabCut algorithm. Shape, color and texture information are combined to construct a real-time object recognition system. The system takes in both RGB-D images from a Kinect sensor and high-resolutions color images from a CCD camera as inputs, and outputs accurate object recognition and pose estimation results that can be used by a robot for object manipulation.

4 Conclusion

By organizing KeJia and TurtleBots in term of hybrid architecture, this multi-robot system shows the ability of dealing with heterogeneity to cooperatively achieve the same goal through global plans. In future, we will study the *continual learning* in multi-robot teams to enable a heterogenous multi-robot system to implement more actions than the given and regular action set. we will also study the *scalability* of system in terms of more complex environments as well as larger numbers of KeJias and TurtleBots.

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