

Defining Transfers Between Multiple Service Robots

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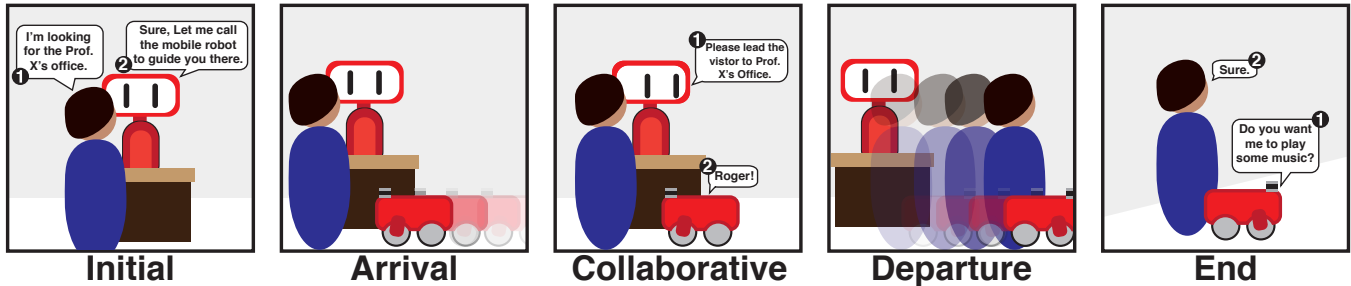


Figure 1: Illustration showing the different stages of a transfer.

ABSTRACT

In a future where many robot assistants support human endeavors, interactions with multiple robots either simultaneously or sequentially will occur. This paper highlights an initial exploration into one type of sequential interaction, which we call “transfers” between multiple service robots. We defined the act of transferring between service robots and further decomposed it into five stages. Our research was informed by a design workshop investigating usage of multiple service robots. We also identified open design and research questions on this topic.

CCS CONCEPTS

• **Human-centered computing** → HCI theory, concepts and models.

KEYWORDS

multi-robot; multi-robot human interaction; transfer; robot transfer

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1 INTRODUCTION

Human-robot interaction (HRI) researchers have not only begun to explore users’ perceptions of multiple robots [1, 2], but have also used them to present information [4, 6], make conversations

more coherent [12], and improve overall system efficiency [5]. In those scenarios, users were often introduced to multiple robots simultaneously, but this might not always be possible in real-world applications. For example, a robot might be delayed due to technical issues and arrive after the start of an interaction, or a robot might summon a second robot with capabilities that are better-suited to the task. More knowledge is needed on how transitions between single-robot interaction and multi-robot interaction should occur.

There has been sparse work exploring these transitions. Shiomi et al. [7] described a proof-of-concept multi-robot mall guidance system where one robot sometimes led a user to another robot who introduced the store. Our prior work [8] investigated how heterogeneous robot teams should interact with each other in such scenarios. Participants interacted with a stationary robot which summoned a mobile robot to guide them. Participants preferred robots that communicated with each other in a way that mimicked human social norms. In this work, we seek to further explore scenarios where users **transfer interactions from one robot to another**, and to identify important unanswered questions in this space.

2 DEFINING TRANSFERS

We define a transfer as the high-level action where one robot hands off its interaction with a user to another robot. This transfer can happen in a co-located setting or remotely. During a co-located transfer, the interaction goes through the following five stages (illustrated in Figure 1):

Initial In the initial phase, the user interacts with the robot in a 1-on-1 setting.

Arrival This stage begins when the user is aware of the second robot and ends when the robot joins the interaction. The user and the first robot may pause their interaction and reorient themselves upon the arrival of the second robot. The interaction changes from 1-to-1 to multi-robot.

Collaborative Before the first robot hands off the user to the second, it may interact with it or the user, i.e., by introducing the robot or communicating a transfer of information.

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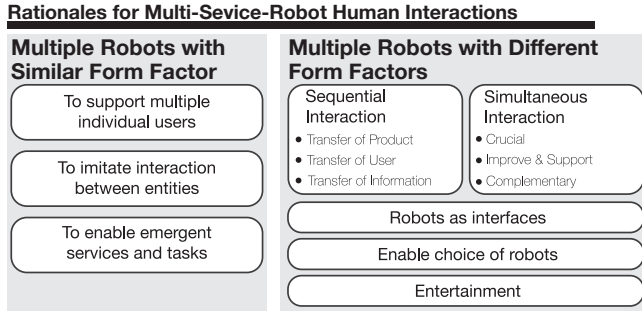


Figure 2: Rationales for deploying multiple service robots.

Departure The second robot and the user disengage from the interaction. The interaction changes back to 1-to-1.

End The user continues interacting 1-to-1 with the second robot.

3 EXPLORATORY DESIGN WORKSHOP

To identify where transitions occur in multi-robot interactions, we collected ideas from researchers on use cases for multiple service robots. We conducted 3 design workshops with 8 participants (2-3 participants per workshop) to gather ideas on how multiple robots would work together to provide services. We constrained ideation to specific spaces (such as a museum or a library) and used ideation cards to select particular types of robots (e.g., mobile robot or drone). The goal of using ideation cards and constraining the exercise was to encourage participants to explore an unknown area and generate many concepts in a relatively small design space [3]. Participants generated a total of 140 different ideas. We analyzed the data using affinity diagramming and identified the key reasons suggested by the participants for deploying multiple service robots (shown in Figure 2).

Our finding also shows that transfers often occur in sequential interactions. Among these transfers, we note three variations:

Transfer of Product In the first variation, multiple robots handle and process the products before engaging the users. An example of this kind of interaction is a situation where food is delivered to a user. The food is prepared by a robot in the kitchen, and is then picked up by the second, mobile robot, which then delivers the food to the user. The user may not be aware of the presence of the first robot.

Transfer of User In this variation, the user initiates the task with one robot, but the user and the task are subsequently transferred to another robot. This kind of transfer often occurs because the first robot is unable to complete the task. For example, a user approaches a stationary robot and asks for directions, so the stationary robot directs a mobile robot to guide the user to their destination. In that case, the stationary robot is physically incapable of completing the task, prompting the transition. In other scenarios, a transition occurs between two robots, both capable of completing the task, due to the fact that one robot is simply better suited for it. For example, a user approaches a humanoid robot to request help finding an object in a warehouse store, but instead of the humanoid robot itself performing the task, a closer and faster mobile robot retrieves the object.

Transfer of Information In the last variation, instead of physical entities, information is transferred between robots. This type of interaction could be either invisible or visible to the user. An example of an invisible transfer is for a flying robot to detect that a person needs a particular item and directs a ground robot to bring the item to the person. From the user’s perspective, they may not realize they are actually interacting with multiple robots. A visible example could be a tabletop robot in a restaurant that monitors when a group is ready for dessert and asks for confirmation before calling another robot to deliver it.

4 OPEN QUESTIONS

As shown in prior work and supported by the work here, there are multiple challenges in understanding and designing transfer between service robots. We identified some open questions in this space that warrant further exploration.

Social Interaction Between Robots While prior work [8] has shown that robot-to-robot interaction during transfer should follow social norms, there has been little exploration of the perceived relationships between robots. Robots can be designed as peers, a boss and its subordinate, or even a main character and a sidekick [10]. How would different relationships influence users’ perceptions of the robots?

Information Exchange During Transfer Williams et al. [11] found that covert transfers of information between robots were perceived as creepy by the users. During a transfer, how should the exchange of information be designed? This is especially important during remote transfers (where the user meets the second robot without the presence of the first robot). How should the robots exchange information in a transparent way that will instill trust?

Proxemics and Spatial Formations How should a robot position itself when joining an existing 1-to-1 interaction? Prior work has shown the importance of appropriate spatial formations among humans and robots in group settings [9]. As the robots and user become a larger group, how should multiple robots coordinate their positions in a way that follows human social norms?

Determining Suitability of Transfer While some transfers are unavoidable for practical reasons (e.g., because one robot is physically unable to complete the task), some transfers could be optional and beneficial only for the user or the stakeholders. For instance, when robots guide users between buildings, robot owners or other stakeholders might want individual robots to stay within or near their respective buildings. This could potentially minimize the wasted time each robot spends not completing other tasks in their own building. However, too many transfers may lead to a bad experience for the users. How should a system reason about suitability of transfer in different scenarios and tasks?

Understanding these challenges will enable designers to not only create better interactions involving multiple robots, but also help select the best robots for different components of a task in support of a holistic experience for the user.

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