Design of a Human Multi-Robot Interaction Medium of Cognitive Perception

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***Abstract*—We present a new multi-robot system as a means of creating a visual communication cue that can add dynamic illustration to static figures or diagrams to enhance the power of delivery and improve an audience's attention. The proposed idea is that when a presenter/speaker writes something such as a shape or letter on a whiteboard table, multiple mobile robots trace the shape or letter while dynamically expressing it. The dynamic movement of multi-robots will further stimulate the cognitive perception of the audience with handwriting, positively affecting the comprehension of content. To do this, we apply image processing algorithms to extract feature points from a handwritten shape or letter while a task allocation algorithm deploys multi-robots on the feature points to highlight the shape or letter. We present preliminary experiment results that verify the proposed system with various characters and letters such as the English alphabet.**

***Index Terms*—human-robot interaction, multi-robot systems, robot for learning, cognitive perception.**

I. Introduction

With the growth of advanced technology, various methods to deliver messages to others have recently emerged in the world, such as image, video, electronic devices, and robots [1]. However, people prefer to use a handwriting or speaking method rather than other ways of self-expression since these are the most easily available on a daily basis. In a school or work environments, for example, presenters often use handwriting along with oral speech to effectively explain and share ideas with the audience. Although this method is easy to implement, it may not be enough to effectively convey messages or attract attention.

Mayer and Fiorella [2] addressed several instructional principles, including signaling, temporal contiguity, and segmenting, that could effectively present textual and pictorial information. Among the principles, they claimed that signaling (i.e., pointing, highlighting, hand-writing) is the most effective way for people to perceive the significant information and learn complex materials. In this regard, dynamic representations with moving objects could support the signaling by directing people attention compared to static representations (i.e., diagrams, figures) [3]. It could enhance the handwriting effect to deliver information to audiences. In this paper, we present multi-robots as a means of creating a visual communication cue that can add dynamic illustration to static figures or diagrams. It could help presenters easily highlight important information and guide audiences to perceive and understand information. While numerous studies present robots that can communicate and socially engage with people [4], it is less understood how multi-robots can be used to effectively present visual information. In this regard, we propose a real-time control system that could effectively support communication between a presenter and an audience by highlighting information with multi-robots.

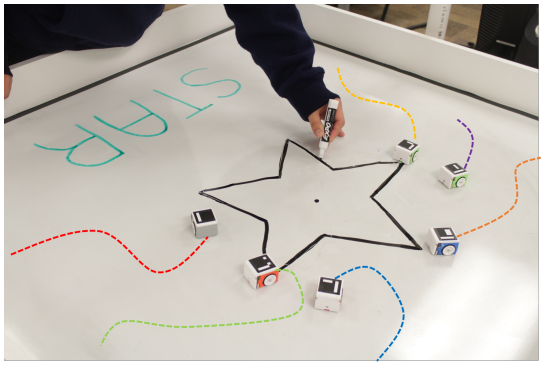

Fig. 1. An application of the proposed interaction medium: A user draws a star on the whiteboard table, and multi-robots reach their desired locations to visualize the star.

II. System Design

The main purpose of this study is to improve communication between speakers and listeners, with emphasis on the delivery of messages, by having multiple robots stimulate cognitive processes. Thus, as an appropriate solution, this study proposes a human-robot interaction medium as shown in Fig. 1. In this system, robots are able to automatically avoid collision and maintain a relative distance from each other [5]. A common whiteboard is installed for an input window between humans and robots. Then, an overhead camera receives real-time image data to generate the commands that robots follow. Data exchange/collection between machines is enabled through the Robot Operating System (ROS). A complete cycle of the proposed medium for the shape of a star is illustrated

This study was partially supported by Award No. 2017-R2-CX-0001, awarded by the National Institute of Justice, Office of Justice Programs, U.S. Department of Justice.

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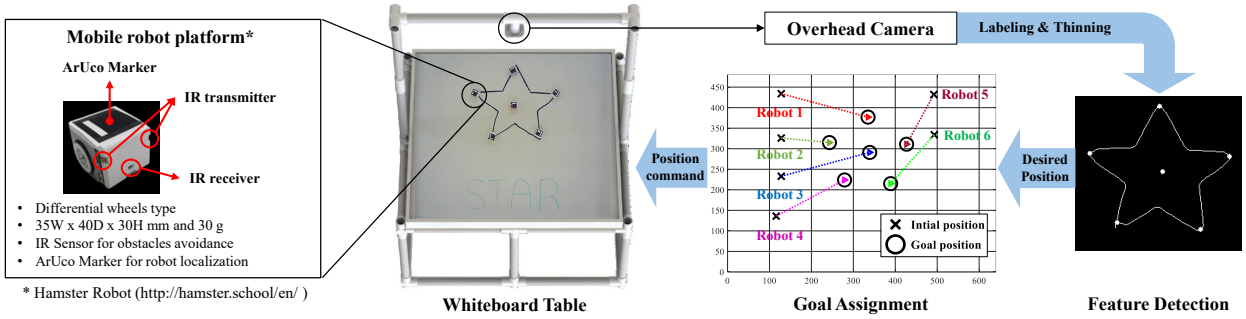

Fig. 2. A complete cycle of the proposed interaction medium. Each task is completed in real-time.

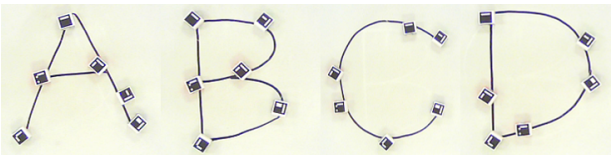

Fig. 3. Other examples. A full demonstration is available at https://youtu.be/i6HtzHSfXWg.

in Fig. 2. In particular, the following tasks are considered and achieved.

1) Design Criteria: The proposed system is developed with the specific design considerations: *accessibility* – enable any type/range of users to utilize without additional background; *intuitivity* – enable intuitive interaction and lower the communication barrier between human and robot; *modularity* – enable use with a variety of user input, such as shapes, letters, and drawings.

2) Goal Generation: : As the first task, a supervisory control system (Intel Core i7, 4G ram) initializes the proposed system via TCP/IP communication of ROS. Open computer vision (OpenCV) libraries are utilized to capture features of the shape or letter drawn by a user, which are goal positions for each robot, through the overhead camera mounted on the whiteboard table as shown Fig. 2. In order to extract the feature points from the handwritten letter, we apply a labeling and feature detection algorithm.

3) Goal Assignment: The assignment of robots to goal positions is formulated based on generated goal positions and the initial positions of robots. The Hungarian method [6] is used to solve the assignment problem, enabling each robot to reach the goal position with minimum cost. Control input is determined by a proportional controller and collision avoidance using onboard range sensors employed by default.

III. Experiments and Discussion

Illustrative examples of usage are provided to demonstrate the effectiveness of the proposed interaction medium. In this experiment, mobile robots were used on a whiteboard (110 cm^2) that was facing upwards with an overhead camera. With a set up test bed, a user wrote different characters on the board. The proposed system is able to use as many robots as are desired to represent the letters, but in this experiment, six robots were employed for simplicity. As shown in Fig. 2 and Fig. 3, using the overhead camera, robots were able to extract feature points from letters written by a user and conducted the goal allocation depending on the task or distances between robot positions and each feature point. As a result, each robot could move to its goal position to visualize the pattern for each case.

In this paper, we proposed a new interaction method between humans and multi-robots that could effectively present information and support communication between people, and conducted several experiments with fundamental examples to validate our proposed system. During the experiments, six mobile robots reached goal positions generated by image processing and the Hungarian task location algorithm, and traced the letters and shapes written on a whiteboard table to stimulate cognitive perception. Finally, the design criteria we introduced were achieved the proposed system was fully ready-to-use without any additional background after a one-time setup, and it used a typical whiteboard table as a communication medium to improve intuition.

A possible avenue of research to complement this study includes a user study to verify our system with different conditions: (1) a traditional communication medium using only writing and speaking, (2) a media-based medium utilizing videos and images, and (3) the proposed medium employing a multi-robot system.

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