Towards Effective User-Guided Robot Search

(Extended Abstract)

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1. INTRODUCTION

In recent years there has been a growing interest amongst Human-Robot Interaction (HRI) researchers in the usage of robotic systems for exploration or search missions [6, 3, 4].

In the traditional approach to robot supervision by humans, knows as *camera guided teleoperation* [3], the operator navigates the robot while interpreting camera imagery. Both tasks require constant attention, and contribute to operator's workload. Automating the robot navigation task, as suggested in [5], is one possible step to reduce workload. Another step is to eliminate the need to view live video, thus turning the interface to use *asynchronous* video.

Recent work [3] on multi-robot interfaces investigated the usage of asynchronous operation schemes in the context of Urban Search And Rescue (USAR) missions [2]. With the asynchronous approach, robots explore the environment autonomously, while the operator is presented with recorded imagery (*asynchronous*) from the robots' camera, rather than live imagery (*synchronous*).

Asynchronous interfaces have several advantages. First, scaling up the number of robots is easier, since the operator no longer has to observe live video feeds from multiple robots. This can help to reduce operator's workload when the number of robots is increased [4]. Moreover, communication constraints can limit the ability to stream live video from the robots and to control them in real-time. This could severely affect the operator's ability to extract useful information and maintain spatial orientation [1]. With the asynchronous approach however, transmission of recorded images can be much more flexible. Images may be transmitted with a delay (as time no longer affects the user exprience), transmitted in bulks (e.g. where wireless reception is better), or even not transmitted at all (the operator would view the recorded images after the robot explored the area autonomously).

Two major challenges of asynchronous interfaces for robot-based search, are how to select the most relevant imagery to display, and how to display it to the operator. A recent approach suggests storing the images in a database and ordering them according to a utility value, which is computed by the image area that was not already seen [4]. Users can then view images according to that order, and navigate through images that were recorded near the selected image. This is a system-guided approach, as the image sequence to view is mainly determined by the system.

In contrast, we propose an asynchronous *user-guided* interface, in which the operator can view the recorded imagery of a given indoor environment, by selecting *points of interest* (POI) on a map. The interface provides the operator with highly-relevant images of the POI from several view points, after applying a dynamic filtering and ranking process over the recorded images. To enable selection of images based on points that appear in them, we develop efficient methods for storage and retrieval of images, possibly indexed by areas covered.

2. RELATED WORK

Multi-robot interfaces have been studied in various contexts, in particular USAR missions. Among these, we note the work of Velagapudi et al. [3], that compared two interfaces: *synchronous* and *asynchronous*. The former was similar to previous multi-robot interfaces (live video), while the latter had no live video display. Instead, an operator directed the search task by assigning robots with waypoints. After reaching the final waypoint, the robot would take a panoramic image of that location, which appeared as a new symbol on a map. The user would then click the symbol to view a panoramic view of the recorded location. Results showed better performance for the *asynchronous* interface when the number of robots increased.

A more recent work [4], which we used as a benchmark, compared two interfaces for multi-robot search: *streaming video* and *image queue*. The robots were autonomous but manual control was allowed. In the *image queue* interface, images from all robots are stored in a database and sorted by utility, which is calculated by the size of visible area that wasn't already seen. The images with the highest utility

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