Multi-robot Control and Interaction with a Hand-held Tablet

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***Abstract*— Real-time interaction with a group of robots is shown with a hand-held tablet, which tracks the robots and computes collision-free trajectories. Efficient algorithms are described and experiments are performed in scenarios with changing illumination. Augmented reality and a multi-player setup are also described.**

I. Introduction

In [1] methods to control a large group of robots were described and experiments were performed with up to fifty robots tracked by an overhead camera and controlled through a fixed PC. In this work a portable and flexible version of the system is presented. This represents a step forwards towards augmented really and human-robot swarm interaction outside of the lab.

II. System description

The basic setup is formed by several differentially-driven robots of 7cm diameter [1], a tablet equipped with a 1920x1080 pixels camera, an optional lens to increase the field of view, and a radio module [1] connected via a mini-Arduino and a serial port adapter. A grey paper mat is used for robustness of the detection and four arena markers (each one with three LEDs) are used to delimiter the arena and robustly compute the homography from pixel to cartesian coordinates. Velocity commands to the robots are broadcasted at about 7Hz, due to the limited computational resources.

III. Detection, control and interaction

Initialization: Since robots send an acknowledgment message back, the number and identity can be inferred. The initial positions are obtained by flashing a unique color code.

In each control loop the following are performed:

Camera position: Homography robustly obtained from the detected position of the three LEDs of each area marker.

Robot detection: The position is obtained by thresholding the image and extracting connected regions [2] followed by erosion/dilation, contour fitting, rectification and ellipse fitting in a small patch around each robot. The orientation is given by two black dots on the top of each robot, found by a mask convolution.

Tracking: An Extended Kalman Filter [3] is employed with prediction based on a diff-drive process model and the sent inputs. Process and measurement covariances are estimated from measured data. Detections and predictions are optimally matched [4]. Time delay compensation is performed since image acquisition and processing takes around 180 ms and send commands are performed after 140 ms.

Interaction: Performed via a touch interface. An image to display [5], a goal position or a trajectory can be given.

Collision avoidance: Collision-free velocities are obtained for all robots following the distributed optimization in velocity space described in [6] and transformed into linear and angular velocity commands broadcasted to the robots.

Augmented reality: Overlaid to the camera image.

Multi-player: Each tablet controls a subgroup of robots.

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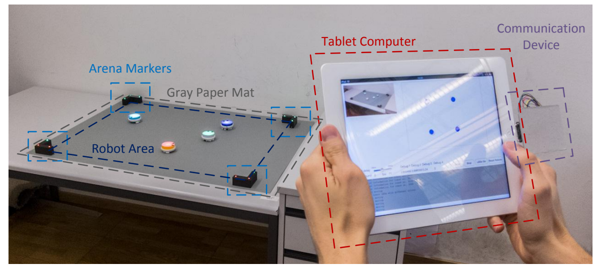

Fig. 1. Several robots and a hand-held tablet for interaction and control.

IV. Experimental Results

Extensive tests show the robustness of the system with different number of robots, with freely moving hand-held tablet, with disturbances (a robot moved by hand) and changes of illumination. Simple augmented reality and multi-player tests are also performed. Representative results are shown in the video. In measurements against a fixed camera system, tracking error has been identified to be below 10mm.

V. Conclusion

Real-time interaction with a robot swarm, including multi-player and augmented reality, has been achieved via a hand held tablet where tracking and control are performed.

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