A Theatrical Mobile-Dexterous Robot Directed through Shared Autonomy

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ABSTRACT

We present the deployment of a 16-DoF dual-arm mobile manipulator as an on-stage actor in the MIT2016 Pageant, a 60 minute live play performed for the centennial celebration of the Massachusetts Institute of Technology campus move from Boston to Cambridge. The robot performed using expressive motions, navigated a 250ft-long thrust stage through a wireless connection, and was directed remotely by a human operator using a shared autonomy system. We report on the technical framework and human-robot interaction that enabled the performance, including motion planning, coordination of action with human actors, and the challenges in navigation, manipulation, perception and system reliability.

1. INTRODUCTION

In 2016 the Massachusetts Institute of Technology celebrated the centennial of the Intitute's move from Boston to Cambridge. The celebrations concluded with **Mind and Hand: A Pageant!**, a multimedia theatrical play staged at MIT's iconic *Killian Court* in front of 6000 spectators [1]. *Mens* and *Manus*, frozen on the MIT seal for almost two centuries, were woken by a robot that catalyzed a discussion regarding the core values of research and innovation, arts and sciences. The robot was played by Optimus, our 16-DoF mobile manipulator, directed remotely by a human operator using a shared autonomy system. The fielded robot performed using expressive motions and poses, which synchronized with pre-recorded sound of the robot's speech and the live dialogue of the human actors. We report on the challenges of translating and hardening research on learning and planning for manipulation using shared autonomy [3][2], for use in an interactive live performance, outdoors and at night-time, with light rain and mist. To our knowledge, this is the first time a remote robot has been successfully deployed as a live performer in a play of this scale with these technical requirements. The presented video is available at http://people.csail.mit.edu/cdarpino/MIT2016/

System reliability was an important requirement. The system behaviors were tested during the preceding months by replicating some of the situations for the robot, such as the ability to drive on a ramp while carrying a large pennant, turn on the stage surface, achieve reliable WiFi connectivity at a 250ft distance, and run for a minimum of 90-minutes duration using on-board power.

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Figure 1: (a) Operator at the off-stage OCU. (b) Optimus robot on the stage. Photos by Neel Shah and Dominick Reuter.

2. TECHNICAL APPROACH

Our approach used a shared autonomy framework, where the cognitive abilities of a human operator and the planning and perception capabilities of the robot are integrated through a human-robot interaction system. Fig.1 shows the off-stage operator control unit (OCU), while the robot is performing on-stage together with human actors.

Expressive motion of the two arms and torso of the robot was achieved through on-line planning with a human supervisor in-the-loop. Poses (i.e. "keyframes") were designed in advance through rehearsals of interaction between the robot and the actors to complement the robot's script through embodiment. During the performance, the off-stage human operator followed the cues from the stage manager to indicate the appropriate timing of robot action with the dialogue. Upon this cue, an optimization-based motion planner was invoked on-line to achieve the specified goal posture corresponding to the current keyframe. The resulting motion plan was displayed to the operator through a 3D user interface and sent for execution. The operator had the ability to make changes and replan as needed in case of an unexpected situation.

Optimus' participation in the play also involved untethered navigation of the 250ft-long thrust stage. Achieving reliable autonomous navigation using visual odometry, localization and mapping was challenging due to extreme lighting conditions that affected vision sensors, multiple dynamic obstacles and lack of features for mapping with lidar, and a compressed timeline for testing on the physical stage. We chose to use teleoperation for the navigation segments. The operator maintained situational awareness using cameras, as direct line of sight was not possible at all times.

3. REFERENCES

[1] MIT2016 online archival. 2016. http://mit2016.mit.edu/movingday/pageant.

[2] P. Marion, R. Deits, A. Valenzuela, C. Pérez D'Arpino, G. Izatt, L. Manuelli, M. Antone, H. Dai, T. Koolen, J. Carter, R. Tedrake, M. Fallon, and S. Kuindersma. Director: A user interface designed for robot operation with shared autonomy. *Journal of Field Robotics*, 2016. http://dx.doi.org/10.1002/rob.21681.

[3] C. Pérez-D'Arpino and J. A. Shah. C-LEARN: Learning geometric constraints from demonstrations for multi-step manipulation in shared autonomy. In *IEEE ICRA 2017, To Appear*, 2017. http://people.csail.mit.edu/cdarpino/CLEARN/.