Challenges and Advancements in Telepresence Frameworks; from Medicine to Autonomous Systems

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I. INTRODUCTION

Telepresence is the technology that allows human beings to remotely monitor, supervise, and control a wide variety of tasks. These tasks range from medical examinations to space discovery [1]. Teleoperation, as the underlying foundation of telepresence, saves money and lives by replacing and relocating human elements from dangerous or harmful environments such as factories' production lines, mines, ports, logistic centres, and so on. On the other hand, this technology can improve life quality by offering healthcare services to remote and rural areas, where access to clinical experts is dangerously limited.

Moreover, in the context of autonomous systems, telepresence can provide the human elements, including operators and users of various applications, with the ability to either deliver or receive same services without physical limitations that degrade the quality of the corresponding service. Teleoperative capability of autonomous systems provides supervisory control, observability, and interruption, if needed, to increase the reliability and trustworthiness of the autonomous agent. Furthermore, with teleoperated autonomous systems it is possible to manage multiple agents centrally, but in a distributed fashion. This will not only increase the efficiency and effectiveness, but also improve the scalability of such systems. On the other hand, teleoperation in autonomous systems offers a great framework to generate considerable amount of expert demonstrations for advanced deep learning approaches such as reinforcement and imitation learning, in which access to expert policy is a critical challenge. Whereas, with operating and commanding an agent remotely in the desired working environment, generating and collecting state-action pairs in a variety of conditions.

However, teleoperation frameworks generally suffer several threats and challenges, including time delays, uncertainties, safety, and cyber-attacks [2]. Time delay is one of the most critical factors that should be taken into account in the design and development of teleoperation systems of any kind. Transmission of command/control and sensory information signals through a communication medium between the two main sides of a teleoperation platform, being the operator and teleoperator, is critically vulnerable to latency and uncertainties [3]. Delays in those transmissions will negatively affect the stability and performance of the teleoperation task. Moreover, designing a safe and secure teleoperation framework is another challenge considering the topology of the network on which the teleoperation is being conducted. In the case of remotely commanding an automated vehicle, it is down to the teleoperation strategy to determine the safety and feasibility of the desired path and manoeuvring before driving it [4], [5]; or in clinical and telehealth applications, cyber-attacks can maliciously steal and manipulate patients' data or jeopardize the clinical teleoperation (remote surgery, medical imaging, rehabilitation, etc.). In all these cases, a robust and reliable teleoperation strategy is a must to guarantee the stable, safe, and effective performance of the desired tasks in a remote environment. In this workshop, we briefly cover the most recent, state-of-the-art techniques and methodologies to tackle these challenges in teleoperation systems.

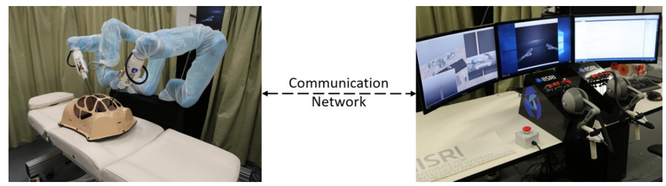

Fig. 1. Am example of a teleoperation system in a clinical application (HEROSURG) [6].

II. CHALLENGES AND ADVANCEMENTS

In this section we cover fundamental challenges in telepresence systems and recent advancements made to handle those challenges. One of the known problems in teleoperation, and robotic generally, is robust grasping of different objects. A recent study have proposed a shared control strategy to enhance the grasping in teleoperated robots [7]. Using a similar idea of shared control techniques, another study focused on a robust performance of aggressive scenarios in autonomous driving [8]. In [9] researchers have developed a dual-robot teleoperation platform that robustly collaborates to achieve the desired task in the remote workspace.

Moreover, human-robots interaction and collaboration have been studied well during the last decade. A recent study in [10] trained a neural network to adaptively understand and predict basic physical interactions between a human hand

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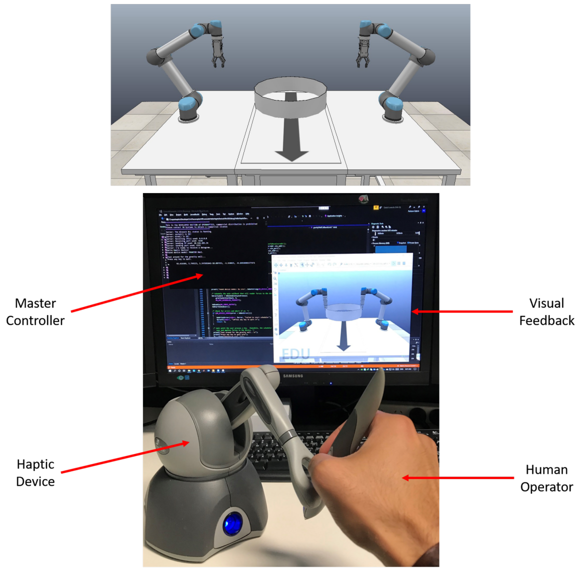

Fig. 2. A robust dual-robot teleoperation framework [9].

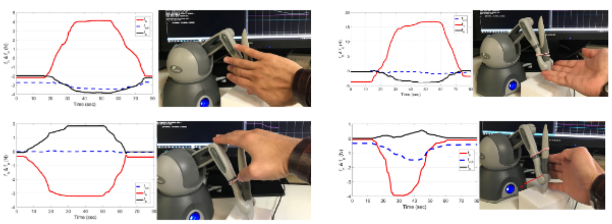

Fig. 3. An adaptive predictive awareness technique in human-robot interaction [10].

and a haptic device. In another study the researchers have developed a stable filtering approach for medical telepresence applications [11]. Furthermore, some studies have focused on the cyber-security challenges of telepresence systems, especially in the domain of novel 5G and cloud computing era [13]. These research studies investigate the possibilities of threats and cyber attacks into a telepresence platform being provided on cloud services.

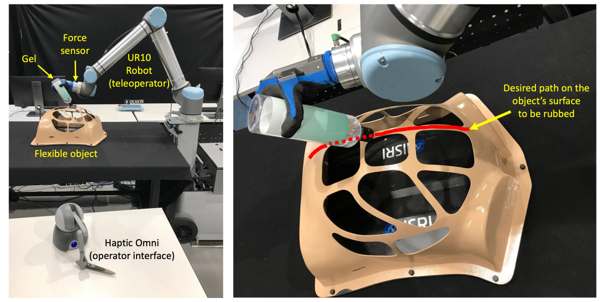

Fig. 4. A stable neural network control for telepresence solutions in medical applications [11].

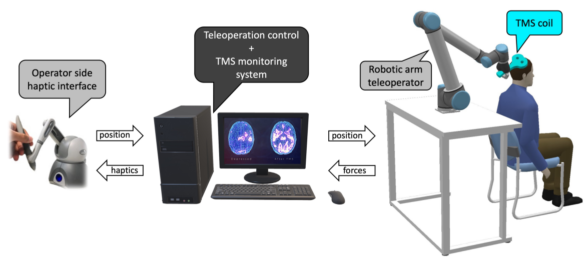

Fig. 5. A telepresence application for clinical TMS studies [12].

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