Efficient Concurrent Operations of Telepresence Avatars

Jong-Hoon Kim, Nagarajan Prabakar, Cynthia Tope
Discovery Lab, School of Computing and Information Sciences
Florida International University, Miami, FL 33199, USA
kimj@cis.fiu.edu

Abstract**-- Telepresence robot extends operation in remote locations as avatars. The remote physical presence application will enable individuals with mobility limitations such as disabled veteran or police officer to perform regular duties through telepresence robots known as avatars or TeleBots. Certain scenarios require many officers to operate on several TeleBots (1:1, 1:many, many:1, or many:many) in the same service area. Thus, we need an intelligent, fault tolerant management system to support these scenarios.**

This system requires dynamic resource allocation such as communication bandwidth, battery power, spatial proximity, etc. In addition, conflicts among the concurrent telepresence operations need to be resolved efficiently.

We propose a novel architecture that provides a fault tolerant multi telepresence robot Management System. This system will allow us to coordinate the assignment, scheduling, monitoring, and administrating multi telepresence robots and multi operators efficiently. Further, we present strategies to resolve conflicts among concurrent operations.

Index Terms**—concurrent transaction, intelligent system; telepresence robot**

I. Introduction

Recent advancements in computing technologies both in hardware and software and the importance of robotics to assist people with mobility, have accelerated awareness of robotics globally. In the past, fully autonomous mobile robots were very expensive and had limited access to public. However, industrial static robots were used in large scale for manufacturing to increase industrial productivity. Recent realization on the significance of robots in our society has led to National Robotics Initiative with involvement from most of the federal organizations.

Currently, the robotics education is being taken more seriously and introduced at the elementary education. This is also been supported with inexpensive electronic components such as controllers, servo motors, and CPUs. Also, the creation of robot with custom models is feasible with 3-D design tools such as AutoCAD, SolidWorks, etc. and its fabrication using 3-D printers make the robotics study viable. Further, the open source project Robotic Operating System (ROS) [2] enables people at large scale to engage in robotics education and research.

The next section addresses the issues related to telepresence robots. Subsequently, we describe our proposed management system for multi-telepresence robots as well as its architecture and implementation. In the last section, we present performance studies for this system and conclusions.

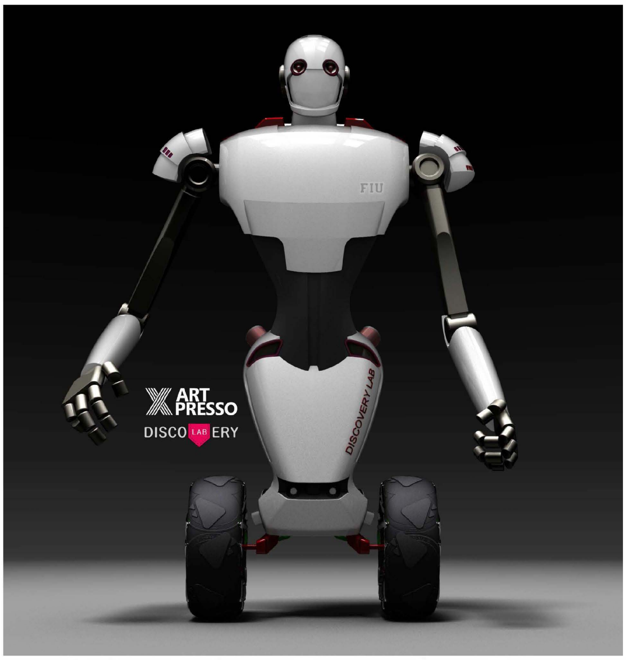

Fig. 1. TeleBot: Telepresence Robot for Remote Surveillance

II. Related Work

Robots facilitate people to perform tasks that are not conducive for humans such as mining, under water exploration, search for land mines, etc. To reduce the cost of robots and to minimize the complexity of the system, telepresence robots play a main role in various applications [4]. In this approach, the remote operator becomes a key factor in making decisions that are context dependent in real-time. This requires a reliable real-time communication between the remote operator and the robot. In addition, the communication must support both visual and audio streaming to assist the operator in making meaningful timely decisions.

For real-time visual communication, effective use of bandwidth utilization and suitable compression algorithms are essential. Further, the use of a head-mount display will enhance the visual communication between the operator and the robot. This device provides a more ergonomic and intuitive feeling to the operator. It allows a natural stereoscopic control of the robot's camera via head movement of the operator, hence providing a threedimensional view [1]. Also, in order to provide a real-world experience to the operator, haptic feedback is necessary. This can be realized by integrating the robotic perception of a remote environment and transferring it to a human user through sensorial environmental feedback. Moreover, gesture control will improve the remote motion control of the social telepresence operation [3]. A telepresence robot with the above features will assist the visually impaired users by increasing their capabilities to interact with different environments [5].

III. SYSTEM OVERVIEW

A telepresence robot (TeleBot) requires either continuous or periodic interaction with a human operator. This type of semi-autonomous TeleBot is cost effective and makes it feasible for mass deployment. In this proposed system, the telepresence robot will become an avatar [10] as shown in Fig. 1, for a disabled veteran or police officer to perform full-time surveillance duties.

The real-time interface between the remote operator and the robot requires efficient and secure wireless multimedia communication with adaptive optimal compression algorithms. Additionally, sensors with haptic feedback, navigational and motion controls are important for providing realistic in-place surveillance. Further, the design and appearance of the robot should project both authority as well as compassion to the public.

The physical dimension of the robot can influence the behavioral response of the public. We have chosen 6' for the height of the robot based on previous studies that have shown that an entity's height plays a key role in how persuasive, attractive, and dominant others judge the entity to be [6]. For a well-managed multiple telepresence operations, an intelligent architecture, TeleBot Management System (TMS), is needed.

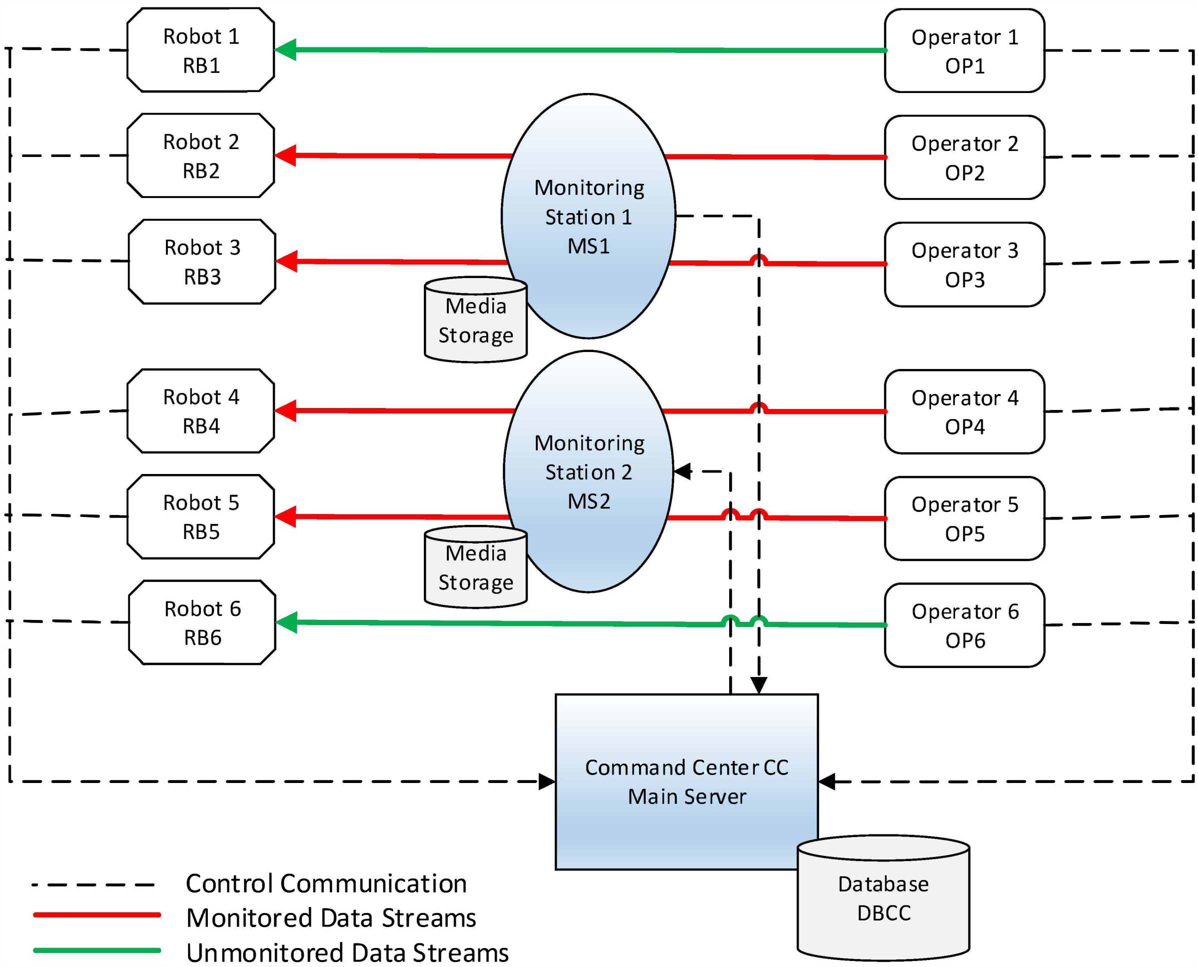

Fig. 2. Architecture of the TeleBot Management System

A. Architecture

The primary components of the TMS are a main server, a well-defined database for information management, monitoring stations, and clients (remote operators as well as TeleBots) as shown in Fig. 2. Monitoring stations support the recording of live interactions of telepresence operations for both quality assurance and accountability. The system also integrates secure communication using authentication and encryption methods.

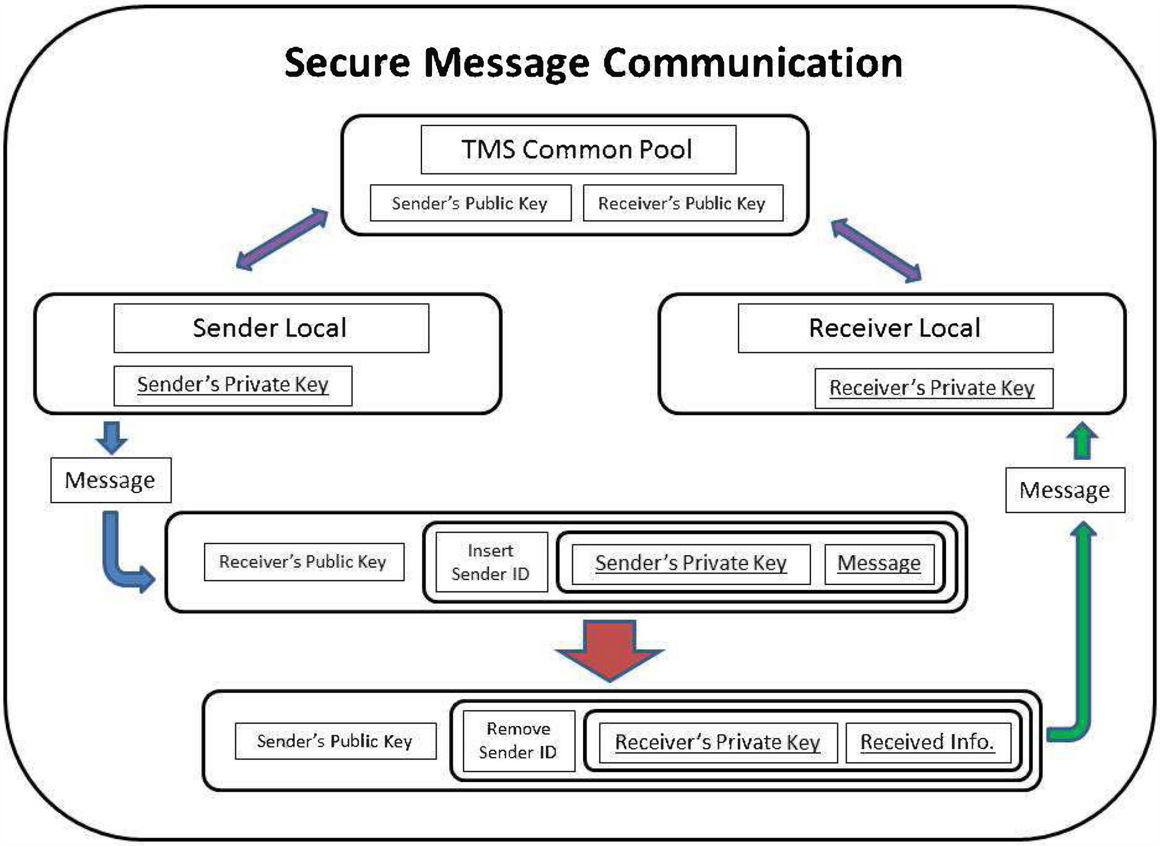

Fig. 3. Secure Message Communication

TMS supports concurrent communication sessions with one session for each pair of clients (a remote operator and a TeleBot). Before the start of each session, the TMS server authenticates the operator and the TeleBot using secure message communication as depicted in Figure 3. This protocol is followed for all message communications to ensure high level of security between any two entities. The public keys of all entities (Operators / TeleBots / MonitoringStations) must be registered apriori with the TMS server. Following the authentication, the server provides a list of available TeleBots for the operation. Once the operator selects a TeleBot, the server sends necessary communication parameters to the operator and the TeleBot as secure messages, so that they can establish a direct communication between them. These parameters include a session key and the public key and IP address of the partner client.

The session communication between an operator and a TeleBot requires reduced communication overhead for transmitting various data streams quickly and at the same time ensures security. These competing requirements are fulfilled with a symmetric session key that is used by all participating entities in the session as shown in fig. 4.

After a session is established, the server will monitor it by checking the status of both clients periodically. If for any reason the communication fails, the clients will inform the server about the failure and then the server will take appropriate actions. These actions may include reconnection attempts between the same clients or start a new session with different clients.

To ensure correctness and accountability, the server will record a session by sending the session key to a monitoring station. After receiving the keys, the monitoring station will record both multimedia streams of the session.

The TMS may employ several monitoring stations to alleviate network congestion and to improve load balancing and spatial proximity of the clients to the monitoring stations. The database structure (schema) and the implementation details are described in [11].

B. Evaluation

This implementation is a prototype of the proposed TMS. The size of the populated sample data sets is not large enough for a full scale evaluation of the system. Moreover, the criticalness of concurrent teleoperations using wireless network should be studied in the field. We expect the quality of communication to decline after the number of simultaneous teleoperations exceeds a threshold and then it will drop drastically with further increase in the number of teleoperations. To overcome this communication contention, we intend to incorporate several data compression strategies [7] such as adaptive resolution, varying sampling rate, and differential spatial compression (high resolution for the central region and low resolution for peripheral regions) for video transmission.

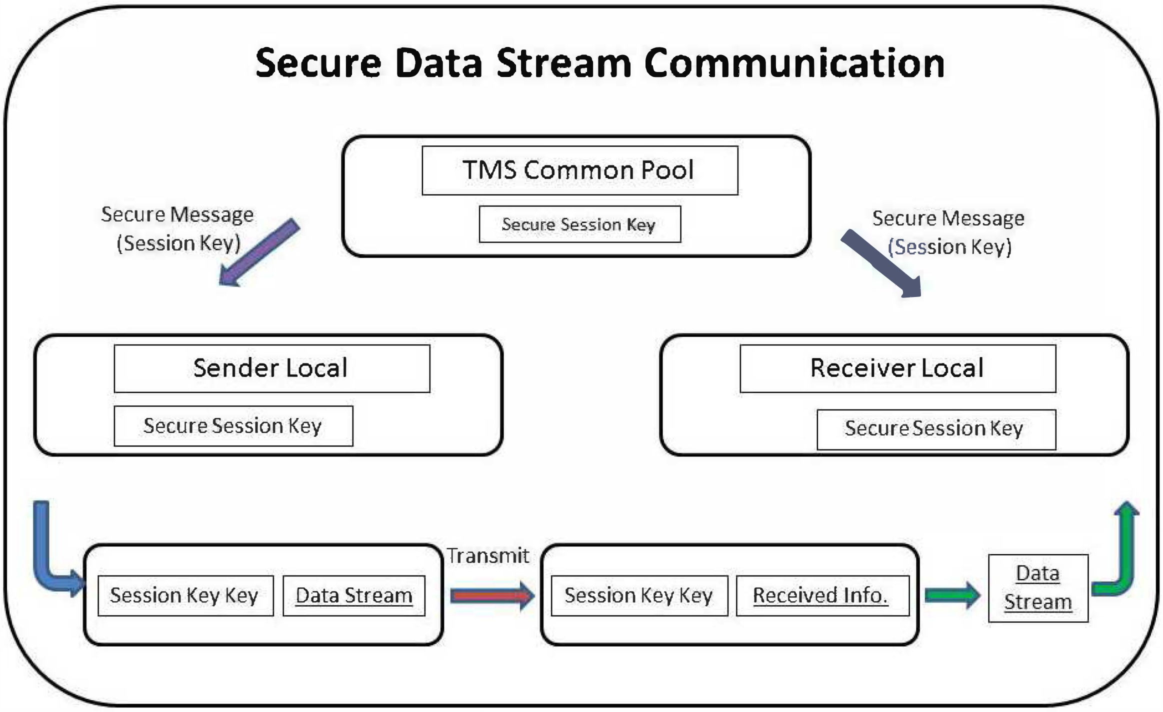

Fig. 4. Secure Data Stream Communication

The monitoring stations store live multimedia streams of selected active sessions. The live recording of the communication depends on the storage media I/O characteristics as well as the network connectivity of the monitoring station. Recording multiple concurrent sessions on the same monitoring station depends on the above parameters and that can be determined in situ.

IV. CONFLICT RESOLUTION OF CONCURRENT OPERATIONS

Four different types of concurrent telepresence operations and the resource conflict strategies are as follows:

- Disjoint (1:1 officer-avatar) pairs of multiple telepesence operations: There is no direct interference among the pairs on their allocated resources.
- 1:many (one officer – many avatars) pairs of concurrent telepresence operations require a strategy for one avatar associated with the officer at any given time, similar to the time sharing operating system model.
- Many:1 (many officers – one avatar) pairs need a well-defined feature partition to specify which features of the avatar are associated with an officer at any given time. Although it is possible to broadcast the output from the avatar (video, audio, haptic signals, etc.) to all officers, each input feature (navigation, head movement, arm movement, etc.) to the avatar must be related to one officer at any moment to prevent ambiguity and contradicting inputs from multiple officers. To prevent this problem in a shared environment, each officer must receive permission from the command center for controlling any input/output feature of the avatar. In this permission control scheme, for each permission approval for access to a set of features, the command center assigns a unique session key for the specific pair of officer-avatar.
- Many:many (many officers – many avatars) pairs require time sharing strategy for officers as well as permission control strategy for shared access to avatar features.

A. *Concurrent transactions*

Certain scenarios in a multi-user environment will require several steps of database operations at the command center that would constitute a database transaction. In this context, officers may initiate transactions for their logical tasks. Concurrent transactions from several officers can lead to problems such as lost update, temporary update, incorrect summary, and unrepeatable read [9]. Further, any pair of transactions with multi-access to shared information can lead to data hazards such as read after write, write after read, and write after write [8,9].

To improve the response (execution) time of transactions, transactions are scheduled together with their operations (steps) interleaved in time. For a given set of transactions, many schedules are possible by interleaving their operations in different ways. Schedules without any interleaving operations, known as serial schedules that are safe and guarantee the elimination of all concurrent problems. However, serial schedules do not improve response time since the operations of transactions are not interleaved.

For achieving both improvement in response time and elimination of all concurrent problems, we need an interleaved schedule whose data hazards are equivalent to the data hazards of any serial schedule. We accomplish this through hazards (conflict) serializability test [9].

The initial prototype of the TeleBot Management System enabled us to evaluate the performance of 1:1 disjoint pairs of telepresence operations. For the evaluation of other types of concurrent operation configurations, we are implementing feature partitions, permission control scheme, scheduling and serializability. This will support all types of concurrent telepresence operations without resource conflicts.

V. CONCLUSION

We presented the TeleBot Management System for administering multiple telepresence operations. This system integrates database, secure network communication, multithreading, and multimedia data compression technologies. We also addressed various types of concurrent telepresence operations and strategies for their resource conflict resolutions. The prototype implementation is being further developed for a full scale deployment. Following this phase, we will be able to conduct real-time in-field performance tests.

When the number of concurrent telepresence operations exceeds the capacity of a TMS, a distributed architecture with a hierarchical or a cluster of TMSs will be essential. For example, a large region such as a state or a country will require such a complex architecture in a collaborative platform. This will be valuable for tracking or enforcing security features at large.

The proposed TMS is based on semi-autonomous approach that makes feasible to design cost effective telepresence robots for several large scale applications such as providing employment for disabled veterans, teleoperations in farming, construction, manufacturing, and medical fields. Moreover, this project will bring a profound social impact for disabled people in improving their social interactions.

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