The 2013 World Congress on
Advances in Nano, Biomechanics, Robotics, and Energy Research (ANBRE13)
Seoul, Korea, August 25-28, 2013

A Smart Multi Telepresence Robot Management System

*Nagarajan Prabakar[1], Cynthia Tope[2] and Jong-Hoon Kim[3]

[1, 2, 3]*Discovery Lab, School of Computing and Information Sciences*
Florida International University, Miami, FL 33199, USA

ABSTRACT

Telepresence robot extends operation in remote locations. This feature can be beneficial for several applications, such as subsea exploration, telesurgery, remote physical presence, etc. Especially, 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 TeleBots. Certain scenarios require more than one TeleBot to operate in the same service area that needs many officers to control many TeleBots. Thus, we need an intelligent, fault tolerant management system to support these scenarios.

This system needs to represent the relationship between the officers and TeleBots that can be 1:1, 1: many, or many:1. Also, it requires dynamic resource allocation such as communication bandwidth, battery power, spatial proximity, etc. In addition, the performance of the system can be affected by network failure, resource shortage, and dynamic changes in service demands and the status of all entities need to be monitored and appropriately reallocated for fault tolerance of the system.

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.

In this paper, we present a novel architecture and implementation of the prototype system, and demonstrate the performance of the system. We analyze the trade-off between the service and resource allocation, and suggest an optimal approach based on case studies.

Keywords: Telepresence robot; intelligent system

1. 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

[1] Professor, E-mail: prabakar@cis.fiu.edu
[2]Undergraduate Student, E-mail: ctope001@fiu.edu
[3] Professor, E-mail: kimj@cis.fiu.edu

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) (Conley 2009)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 asits architecture and implementation. In the last section, we present performance studies for this system and conclusions.

2. 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 (Nishiyama 1998). 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 ahead-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 naturalstereoscopic control of the robot’s camera via head movement of the operator, hence providing a three-dimensional view (Cardenas2013). Also, in order to provide a real-world experience to the operator, haptic feedback isnecessary. 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 (Jalil2012). A telepresence robot with the above features will assist the visually impaired users by increasing their capabilities to interact with different environments(Park2012).

3. PROPOSED SYSTEM

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 as shown in Fig. 1, for a disabled veteran or police officerto perform full-time surveillance duties. The real-time interface between the remote operator and the robot requires efficient and secure wireless multimedia communicationwith 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 (Rae2013). For a well-managed multiple telepresence operations, an intelligent architecture, TeleBot Management System (TMS), is needed.

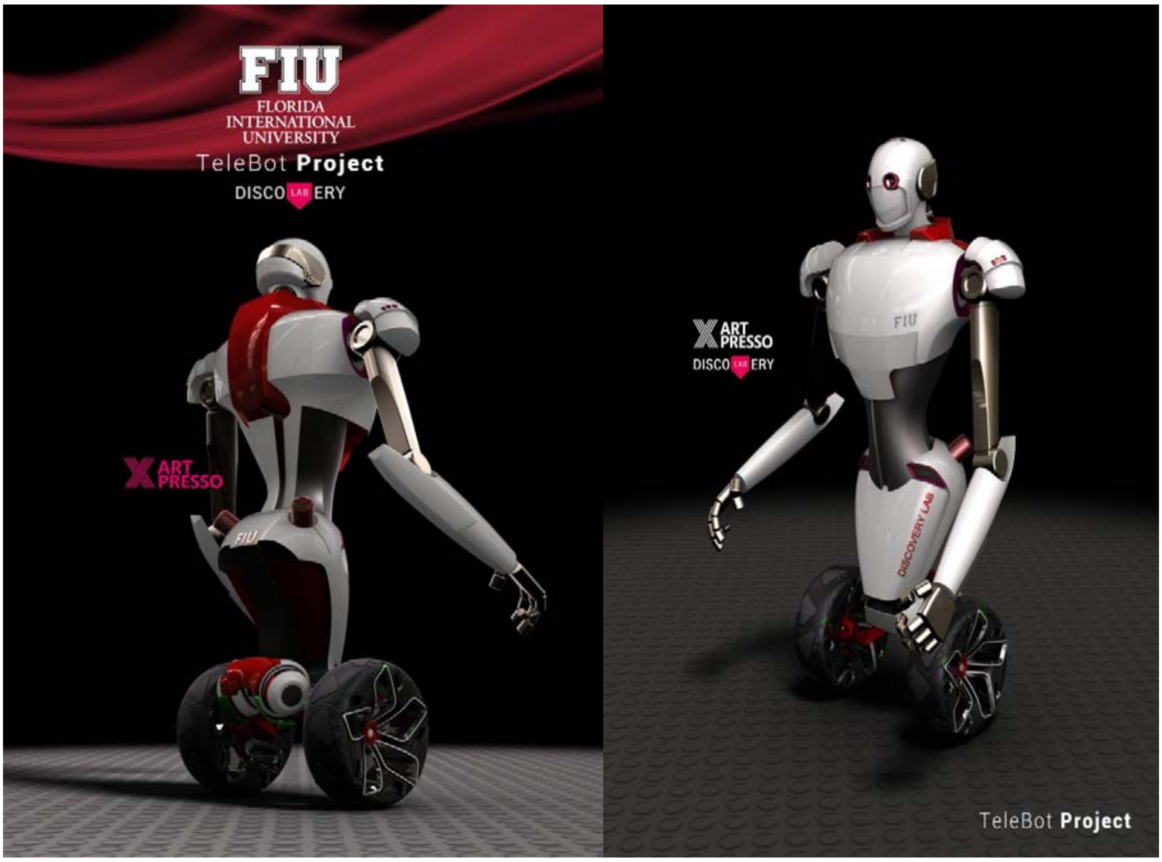


Fig. 1Telebot: Telepresence Robot for Remote Surveillance

3.1 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.

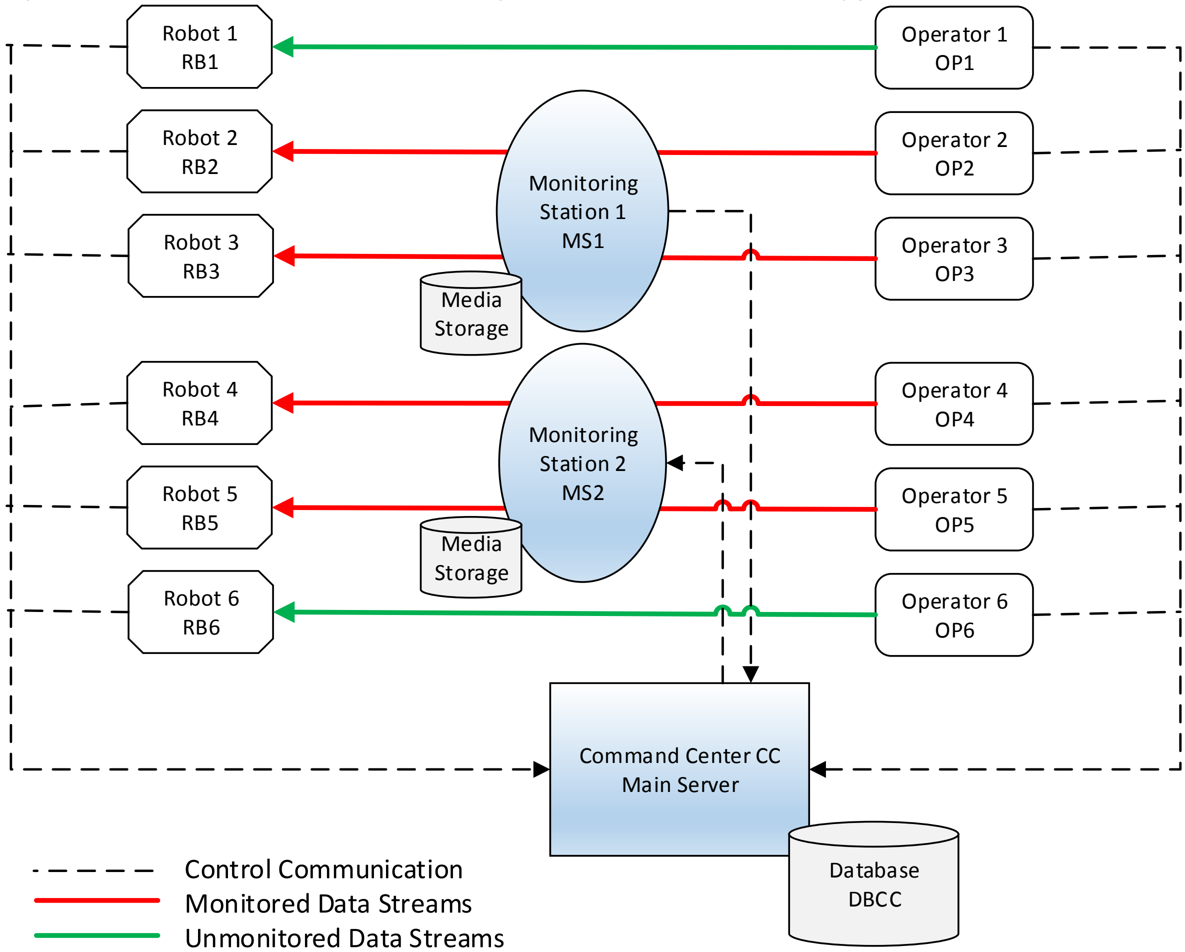


Fig. 2 Architecture of the TeleBot Management System

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 operatorusing the previously stored login information from the database. After 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, 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.After a session is established, the server will monitor it by checking the status of both clientsperiodically. 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. Initial control communications are described in the following use case UML diagram in Fig.3.

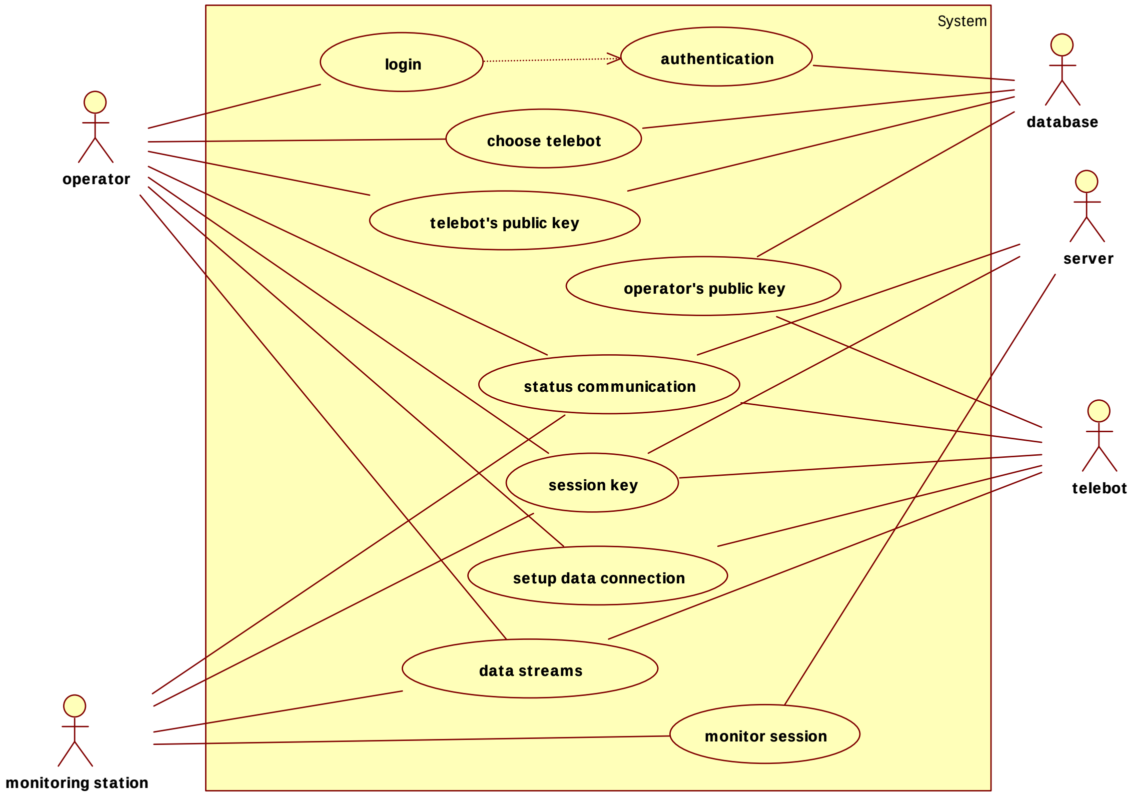


Fig.3 UML Use Case Diagram

To ensure correctness and accountability, the server will record a session by sending the session key toa 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 andspatial proximity of the clients to the monitoring stations.

The database consists of both static and dynamic entities. The static entities contain information that does not change over time such as name, address, social security number, etc. of an operator. The dynamic entities represent time variant information such as login time, session duration, etc. Other entities include “Session” and “Monitoring Station”. The ER diagram in Fig.4 describes the entities and relationships in our database. The database also stores additional information for operators such as language, skill, and disability, to specify special capabilities or limitations. Also, the public key of all entities are stored to establish encrypted and secure connections.

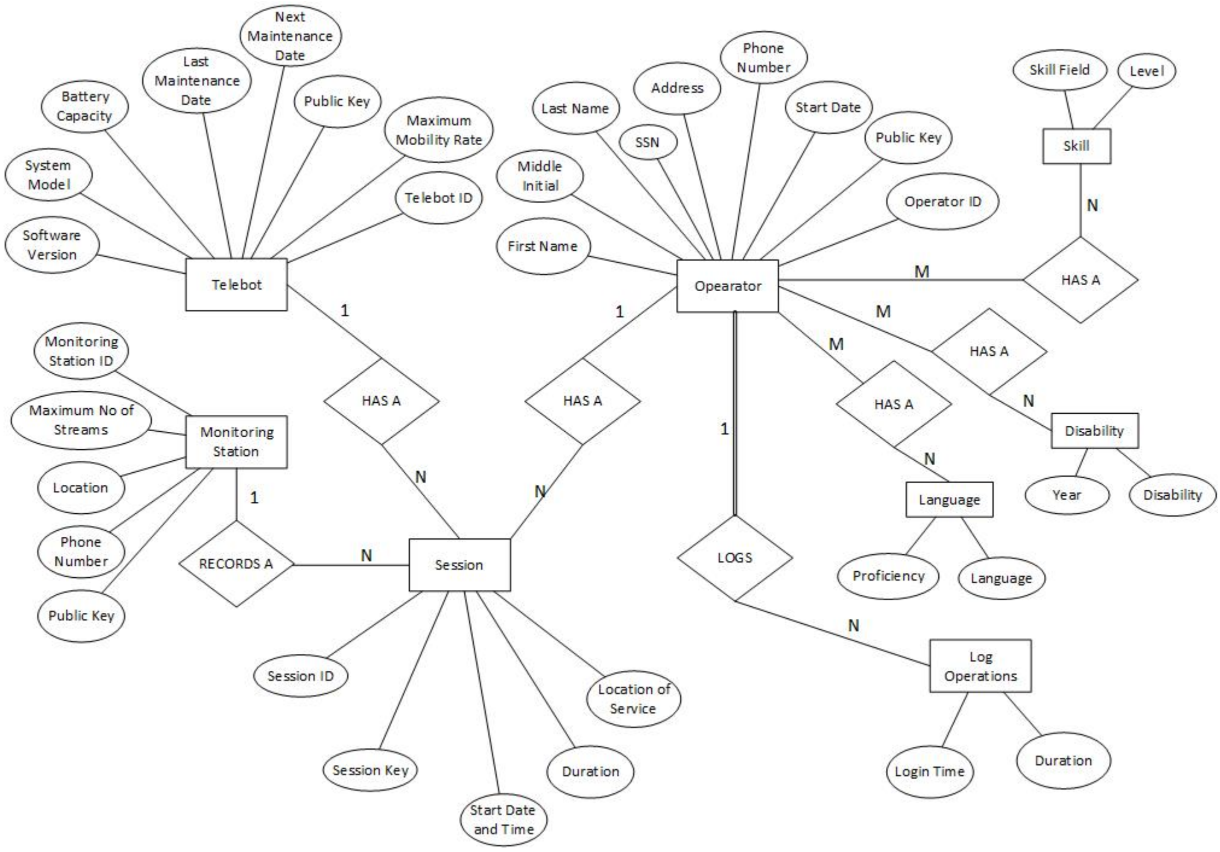


Fig.4Entity - Relationship Diagram for TMS

3.2 Implementation

The TMS is implemented as a high-level network communication program. It is developed as a Java application on Linux platform (Ubuntu). This Java program consists of five major classes and fifty two methods. The program supports multi-threading for a client-server configuration. The software is extended to capture real-time communication statistics for performance evaluation.

The system implementation is illustrated with the following screen shots. Fig. 5A describes the initial login interface for authentication followed by the operator's profile. It consists of personal information and schedule.Also, it includes a telebot selection process with several search criteria. The next screen shot, Fig. 5B, presents the command center's view with geographical information of all available telebots and the different camera views of any selected ongoing telebot session. Finally, the telebot's camera view with battery status and geo-location as seen by the operator is presented in Fig. 5C. The integration of graphical information and the live video streams are currently being developed.

Fig. 5A
Operator View

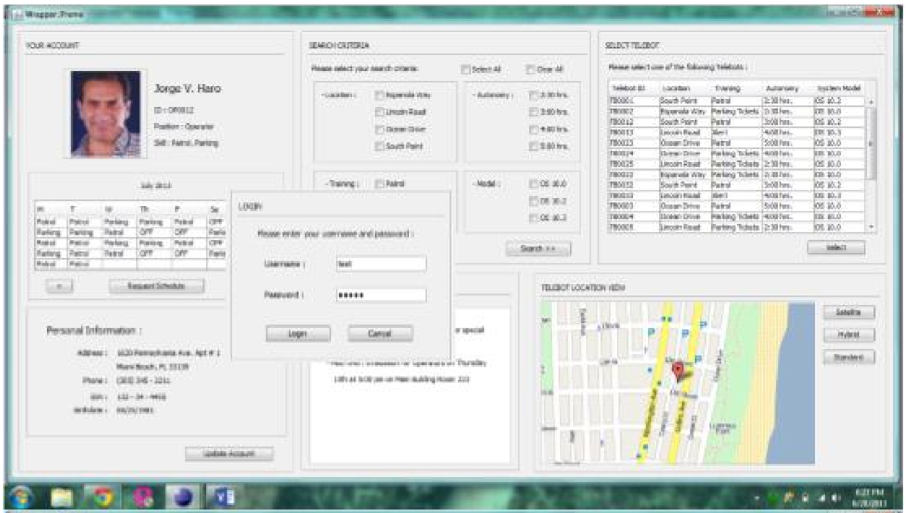


Fig. 5B
Command Center View

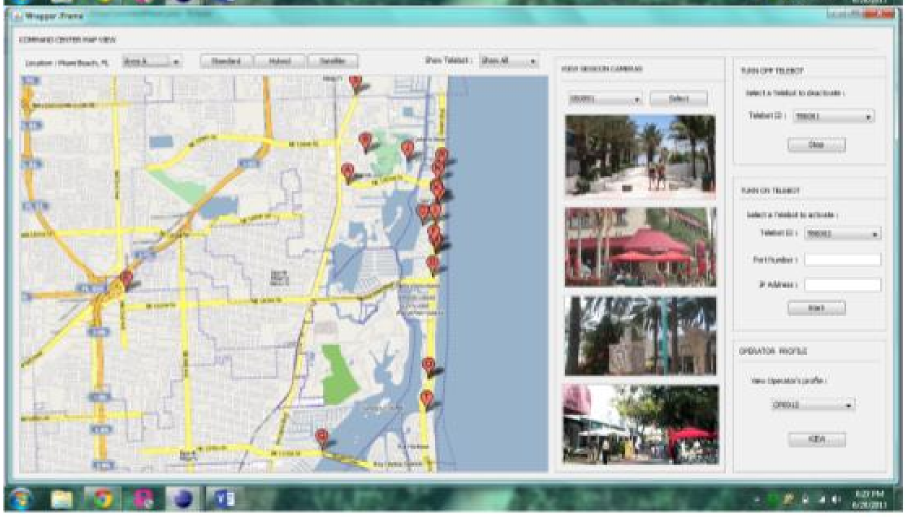
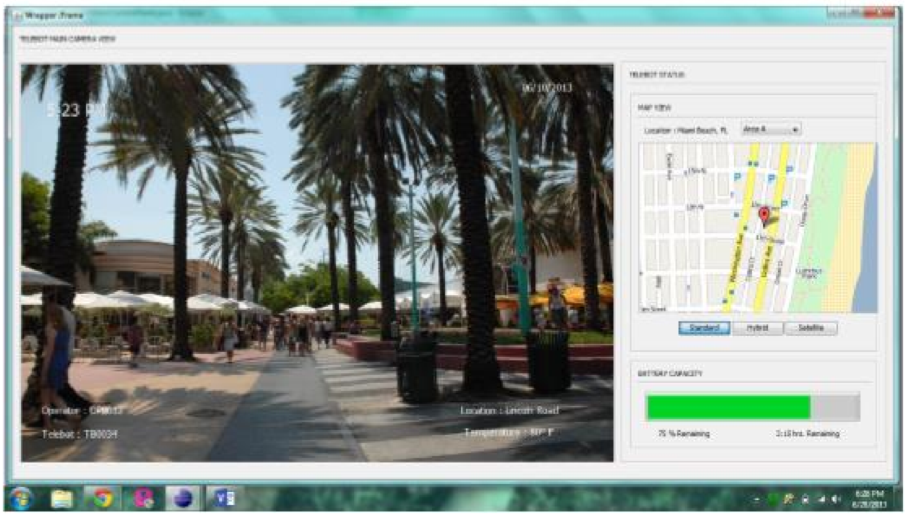


Fig. 5C
Telebot View



The database is designed using MySQL DBMS and the ER schema is mapped into eight tables. For test purposes, the tables are populated with sample data sets. We use PHPMyAdmin to administrate the database and WAMP server to simulate a network on the localhost.

3.3 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 (Tsukahara 2011) such as adaptive resolution, varying sampling rate, and differential spatial compression (high resolution for the central region and low resolution for peripheral regions) forvideo transmission.

The monitoring stations store live multimedia streams of selected active sessions. The live recording of the communicationdepends 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.

4 CONCLUSION

We presented theTeleBot Management System for administering multiple telepresence operations. This system integrates database, secure network communication, multithreading, and multimedia data compression technologies. 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.

5 ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation under Grant No. CNS-1263124. Also, this project is supported in part by State Farm and personal donation by Lieutenant Commander Jeremy Robins, who provided the conceptual theme for this project.

REFERENCES

Cardenas, I., Kim, J. H., (2013), “Advanced Technique for Tele-operated Surgery Using an Intelligent Head-mount Display System”, *Proceedings of the 29th Southern Biomedical Engineering Conference (SBEC),* Miami.

Conley, K., Et Al. (2009), “Documentation.Papers.Ros.com. Retrieved May 25, 2013, from http://www.ros.org.

Jalil, S. B. A., Osburn, B., Huang, J., Barley, M., Et Al. (2012), “Avatars at a Meeting”, *Proceedings of the 13th International Conference of the NZ Chapter of the ACM's Special Interest Group on Human-Computer Interaction*, New York.

Nishiyama, T., Nomura, J., Nakajima, R., Miyanoh, T. (1998), “A Semi-Autonomous Security Robot Employing Telepresence”, *Communications of the ACM*, Vol. 41(5), 198-205.

Park, C. H., Howard, A. M. (2012), “Real World Haptic Exploration for Telepresence of the Visually Impaired”, *HRI '12 Proceedings of the seventh annual ACM/IEEE international conference on Human-Robot Interaction*, New York.

Rae, I., Takayama, L., Mutlu, B. (2013), “The Influence of Height inRobot-Mediated Communication”, *HRI '13 Proceedings of the 8th+ ACM/IEEE international conference on Human-robot interaction,*Piscataway.

Tsukahara, Y., Tomine, T., Sugiura, K. (2011), “Design and Implementationof “Global Studio”:Remote Collaboration Environment with High ResolutionVideo Streaming Software”, *AINTEC '11 Proceedings of the 7th Asian Internet Engineering Conference,* New York.