An Experiment on Communication Assessment for An Ongoing Tele-Surgical Robot Research in Thailand

Syed Saqib Hussain Shah[1,2], Sorayouth Chumnanvej[3] and Jackrit Suthakorn[1,2],*
[1] Department of Biomedical Engineering and [2]Center for Biomedical and Robotics Technology, Faculty of Engineering, Mahidol University, Salaya, Nakorn Pathom, THAILAND
[3]Department of Surgery, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok, THAILAND
*Tel: 0- 2441-2138 Ext. 6446, Fax: 0- 2-441-4254, *Corresponding Author: jackrit.sut@mahidol.ac.th*

Abstract

Robotic tele-surgery is a promising application of robotics to medicine, aiming to extend surgical expertise to remote rural communities and eliminate distance barriers for medical care. In Thailand, most of the population lives in rural areas where expert surgeons and specialty care remain unavailable. Tele-surgery offers an appropriate solution to provide remote surgery and medical care through communication links. Communication plays a vital role in tele-surgery, however problems like transmission time delays, bandwidth constraint, connection rupture, packet loss, although brief, pose a major challenge in robotic tele-surgery. In this study, we tested multi-modality of communication systems i.e. LAN, WLAN, third generation network (3G) and long distance internet communication, which were adopted and tested by our research group. The result shown that LAN system works most effectively with an average latency time of 5 ms, lower than long distance and other forms of communications. Moreover precision and accuracy metrics from the pick and place task test revealed that tasks done on low latency communication were performed with ease while higher latency communication requires the user at the master site to adapt to the latency.

Keywords: *Tele-surgery; Communication; Medical Robotics; Anesthesiologist Monitoring Data;*

1. Introduction

Medical robotics and computer assisted surgery is an emerging area of research in the applications of computers and robotic technology to surgery, planning and execution of surgery operations and training of surgeons. The collaborative efforts between fundamental science, engineering and medicine provide physicians with improved tools and techniques for delivering effective health care. With appropriate communication links, doctors can perform surgery on patients from a distance to rural areas where specialty care is unavailable.

A number of tele-surgeries have been performed in western countries; for example by Marescausx and colleagues, who achieved the first transcontinental tele-surgery, in which the surgeon was in New York City and the patient was in Strasbourg, France, using the commercial laparoscopic robot, ZEUS [1]. M. Anvari et al., established the first tele-surgery procedure using commercial fiber optics [2]. M. C. Cavusoglu et al., developed tele-surgery using a research based laparoscopic robot. [3]

Communication plays a vital role in tele-surgery, which requires high bandwidth from master to slave sites and vice versa, e.g., video stream, voice communication, robot positioning control, and anesthesiologist patient monitoring data. In Thailand most communication systems do not provide Quality of Service (QoS) resulting in a number of errors and difficulties, such as transmission delays, bandwidth constraint, connection rupture packet loss, etc. Although tele-surgery may be the solution for remote community surgical care, the performance and success depends on the well classified communication system.

Tele-Surgical research at our center is developing a Master Console, which can provide both a virtual training system for trainee surgeons and a surgical robot console. The surgical robot acts as an active and passive laparoscopic holder with the capability of remote control.

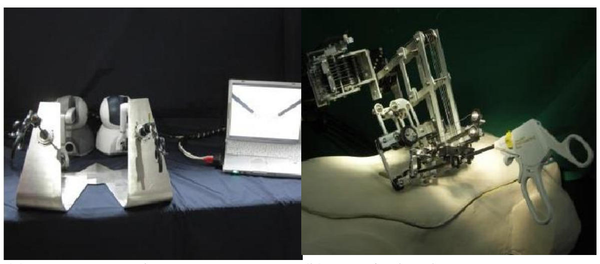
In this study, we tested multi-modality communication systems such as LAN, WLAN, third generation network (3G) and long distance internet communication, which were adopted and tested by our research groups. The data suggest that LAN system of communication works effectively with average latency time of 5 ms quite lower when compared to long distance and other forms of communications. In addition, we design a tele-surgery system, where we setup a pick and place task to test latency for precision and accuracy. The data revealed that tasks done on low latency communication were performed with ease while higher latency communication requires the user at the master site to adapt to the latency.

2. Tele-Surgical Units

Our researchers are designing and developing a surgical robot using a master-slave philosophy with a master (surgeon's console) and a slave (surgical robot located in the operating room), comprising of completely separate units that are IP capable. The whole Tele-Surgical unit will be integrated into the Tele-surgery system with a virtual environment system.

2.1 Master Console: A basic laparoscopic surgical console is being developed with an attachment to a commercial haptic force feedback device, Sensable Phantom Omni. The basic design is shown in Fig. 1 (a), this system will act as a surgical console that connects to the surgical site. [5]

2.2 Surgical Robot: A robot assisted surgical system has also been developed by our researchers for laparoscopic surgery, with arms that are controlled remotely through a sequence of packet-oriented digital commands from the surgeon's console and are delivered through a standard network connection. The basic design of the robot, "MU-LapaRobot," is shown in Fig. 1 (b), [6].



(a). Expert console (b). Surgical Robot

Fig. 1. Ongoing Research of Tele-Surgical system

2.3 Master and Slave System

In recent years, robots have been developed to assist surgeons in performing surgeries. Since these robots are meant for surgeons' use, the design and considerations for safety, reliability and the human–robot interface are of primary importance. One of the most common modes of controlling surgical robots is using a master and slave layout.

At the master site, a robot controller is present with haptic capabilities; the proposed master site is shown in Fig. 2. A master surgical robotic control system with required technology for operating, real time display, monitoring system communication port and a system that will include video, voice and sensing data system.

The slave site will be equipped with "MU LapaRobot"; the proposed slave site is shown in Fig. 2., which is a surgical robot with slave surgical robotic controlling system, real time surgical information display, and communication port to receive and transfer all required data/information. Fig. 2. shows the design of the Master and Slave sites.

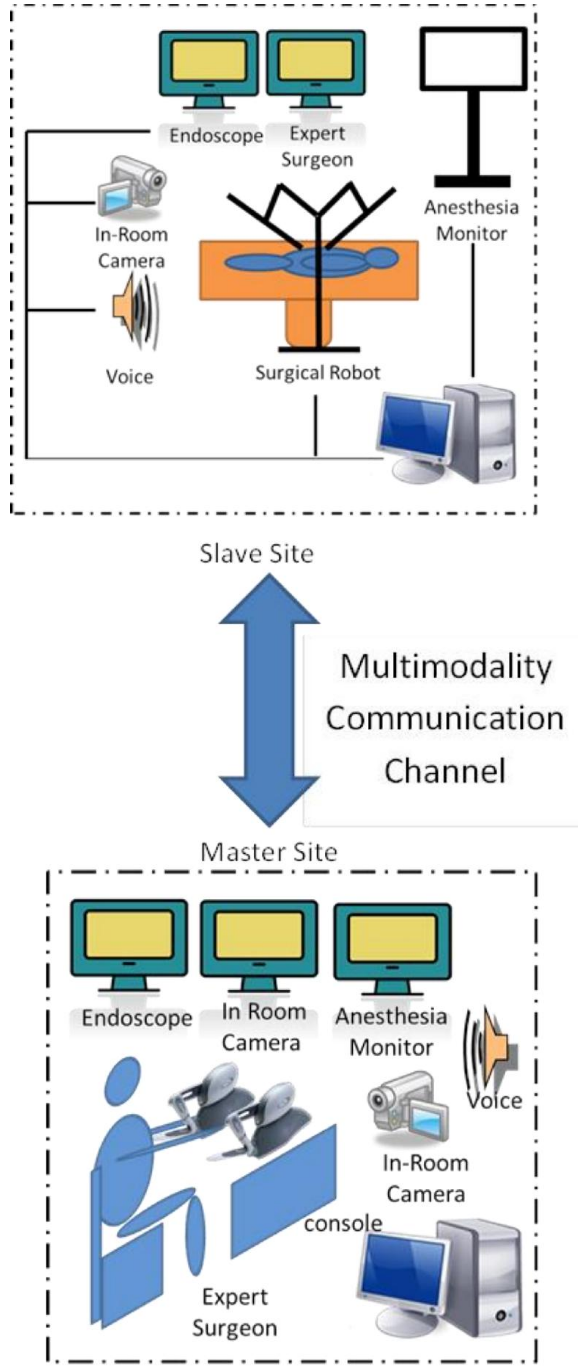


Fig. 2. Master and Slave Site Overall system

2.4 Tele-Control Formulation

The author uses position to position command to control the master and slave site, Fig. 3. shows the homogeneous transformation matrix which is used to compute to the position and orientation of the end effector with respect to the base.

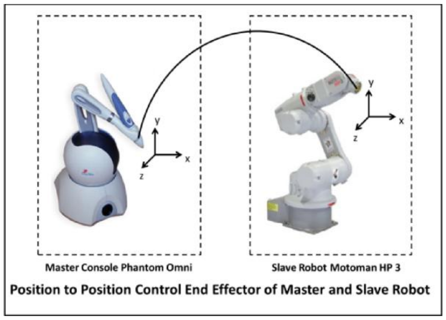


Fig.3. Position to position control of end effector

3. Investigation of Technical Requirement of data and Information for Tele-surgery

In Tele-surgery, a lot of data are needed to be transferred from the master to slave sites and vice versa, e.g., video stream, voice communication, robot control positioning, patient and anesthesiologist monitoring data. All the devices are connected to each other using a standard communication interface. This enables the system to be easily deployed, readjusted or augmented by new tools. Signals from all devices are collected and multiplexed by a switch, creating a single data stream directed by a communication device as shown in Table 1.

Table 1. Required information for Tele-surgery

Master Site	Slave Site
1. Master console 2. Camera for visual contact 3. Audio for voice communication	1. Surgical robot 2. Endoscope 3. Camera for Visual contact / room overview 4. Audio for Voice communication 5. Anesthesiologist data

4. Our Approach

In this study, we tested multi-modality communication systems like LAN, WLAN, third generation network (3G) and long distance internet communication between master and slave for quantitative evaluation of the effect of latency on the performance of tele-surgery.

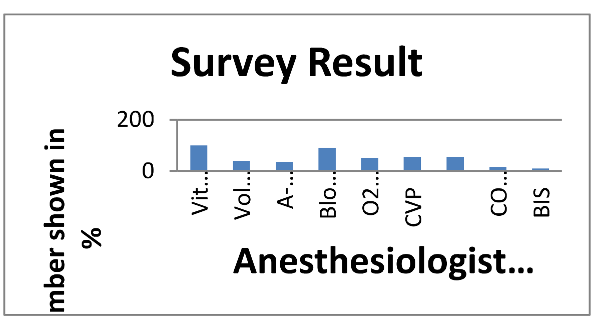


Fig. 4. Result of survey
X axis indicates the required intraoperative data
Y axis indicates the percentage

A survey was conducted about vital signs and other essential physiological observations which are required to be monitor the patient during intraoperative surgery in master site. Results were collected from anesthesiologists and surgeons at Ramathibodi Hospital, Thailand, which is formulated and shown in Fig. 4.

The author earns this information to determine the necessary information for patient physiological monitoring during intraoperative surgery. Different procedures require different monitoring information from the patients.

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4.1 Augmenting System and Information

The essential components of tele-surgery system are master/expert site and slave/surgical site where the master/expert site requires an endoscope camera, inroom Camera, Voice communication, robot controller, and anesthesia monitor, while a surgical robot console, inroom Camera for visual contact, and voice communication are required at the slave site.

4.2 Communication Modality

Although tele-surgery may be the solution for remote community surgical care, the performance and success depends on the well classified communication system. Fig. 3 shows the master and slave site setup used to test multi-modality communication systems like LAN, Wireless LAN, Third Generation Network (3G), Broadband Internet, and a long distance Internet setup, where the distance between the master and slave site was 24 KM. We successfully completed five different modality tests on this system. The commercial network analyzer software “WIRESHARK” was used to capture network activity while performing tele-surgery. This is an open source packet analyzer which captures the performance of various communication systems.

4.3 Communication Location

LAN, Wireless LAN, Third Generation Network (3G), Broadband Internet, communication system were applied to the Tele-surgery system. The master and slave sites were setup in the same room. However for the long distance communication between master and slave sites, data was transferred through internet. In the latter case the master site setup was located at the department of Neurosurgery Ramathibodi Hospital, Mahidol University, which was approximately 24 KM away from the slave site, at the Center for Biomedical and Robotic Technology (BART LAB), Faculty of Engineering, Mahidol University, Salaya. Fig. 5. shows the different modalities of communication that were tested in our experiments, where red, blue and green bars represent minimum, maximum, and average time delay respectively. Fig. 5. shows different modalities of communication from left to right first bar represent blue (Minimum delay) second bars represent red (Maximum delay) and third bar represent green (Average delay), result of the communication tests; comparing time delay of different modalities. Each modality was tested 5 times in between 10-30 minutes. Y axis shows time duration, for each delay, in second and X axis shows the different modalities that were tested.

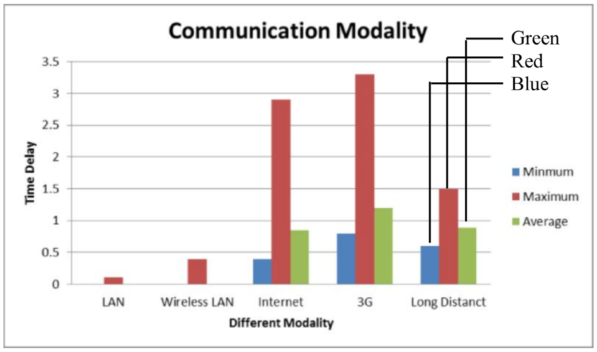

Fig. 5. Communication Modality

5. Experimental Setup and Task

The workspace for our experiment was setup as shown in fig 6 and fig 7. The slave robot was kept under the control of master. In our work, we used Motoman RX 100 arm robot as a slave. The surgeons were required to move the five colored block i.e Red, Black, Yellow, Blue, and White blocks from position A (left) to position B (right) as shown in fig. 6 and 7. The objective of this task was to pick and place in a curve trajectory within the workspace, from Position A to Position B.

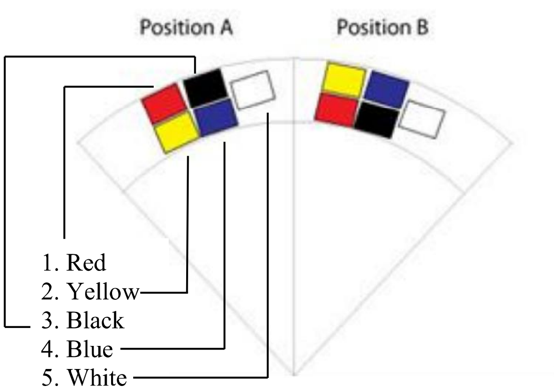

Fig. 6. Workspace of Pick and Place Object

The movement of the colored blocks from position A to position B were designed with a unique sequence i.e the first block surgeon had to moved from position A is white, second blue, third red, forth black, and the fifth is yellow. As shown in fig. 7, a different color sequence is applied at position B, the surgeon was asked to place each block at their respective position. The purpose of this experimental design was to enhance the ability of the surgeon to understand motor movement in two dimension. Figs. 7 and 8. show the setup of the master and slave site, which were located at Ramathibodi Hospital and Mahidol University respectively. Data that were sent from the master site are surgical console data, expert surgeon visual data, and voice communication. On the other hand data sent from the slave site includes surgical robot, endoscope camera, patient and room overview camera, voice communication data and anesthesiologist data.

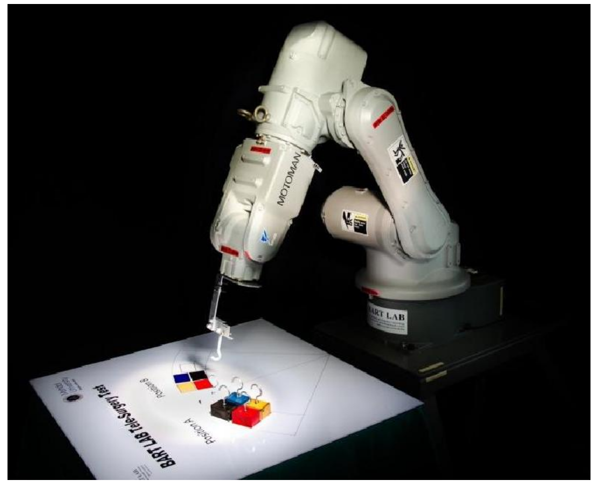

Fig. 7. Slave Site with task setup in Motoman HP 3 Workspace

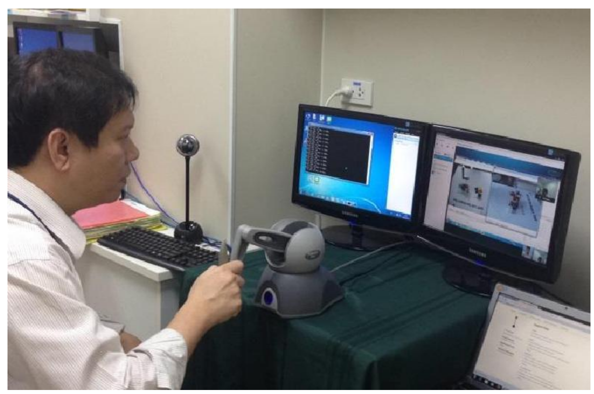

Fig. 8 Expert surgeon performing pick and place task at the master site

6. Result

Our data revealed significant differences between each modality i.e. between the LAN and Wireless LAN setup where master and slave sites are connected to each other in the same network, Wireless LAN found an average delay of 5 ms which is a smaller difference than the LAN network. Both networks experience unnoticeable delay while controlling the robot. While using the other 3 modalities the results reveal much higher latency in each network. The four modalities LAN, Wireless LAN, Internet, and 3G, were tested in the same room, whereas long distance tests were performed between a Master and Slave site, which were 24 km apart.

6.1 Pick and Place Task

The pick and place task in which precision of placement and time consumed in communication was estimated by moving colored blocks from position A by slave robot under the control master robot to position B.

Total 7 trials were conducted. As shown in fig. 8, where X axis indicate number of trials and Y axis shows the time duration (in seconds) taken to place each object from position A to Position B. The average time was 1.25 second. Some trials encountered higher latency while performing the pick and place task where. The maximum time recorded for the task was 3.38 second whereas with very low latency the author could perform the pick and place task with a minimum time of 230 millisecond.

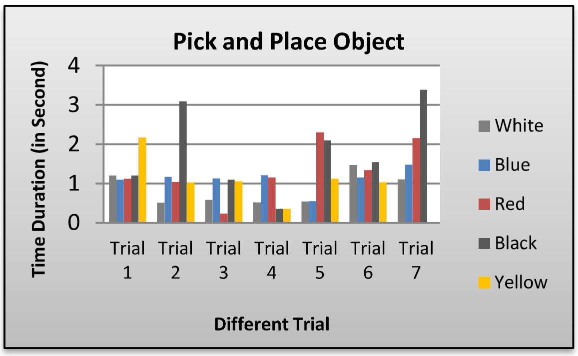

Fig. 8 Pick and Place Objects

7. Discussion

This paper testing a mock up tele-surgery system for communication testing. Multi-modality communication systems show the importance of each modality and how each would affect the transfer of data during a Tele-surgery.

While testing communications for the Tele-system at short distance, LAN and Wireless LAN, the researcher noticed very low latency with an average of 5 milliseconds. On the other hand, the average of 800 milliseconds latency was found for long distance internet.

While performing the pick and place task with low latency communication the experiment is performed with ease, while higher latency requires the master site to adapt to the latency.

8. Conclusion and Future

This paper presents a development of a prototype of a tele-surgery system. The tele-surgery system includes master and slave site robots with important data which need to be sent and received. This research also implements multi-modality communication systems. In the future, QoS system can be applied to our system in order to improve latency of network, and this system can be applied to our tele-surgical system.

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