

Development of Graphical User Interface (GUI) for Surgery Assistance Application

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ABSTRACT

Telemedicine is a technology that promotes patient engagement and makes healthcare more affordable and accessible. Telehealth technologies are used in healthcare settings such as teleconferencing, patient data transfer, and shared remote learning. However, current teleconferencing has limited ability to perform annotation on real-time videos. The proposed surgery assistance system would revolutionize the medical surgery industries where surgery can be monitored remotely by a surgical specialist with minimal assistance. The supervising surgeon can provide assistance to his subordinates in the operating room by annotating on videos of body parts transmitted live then the annotation will be projected directly onto the patient's body as physician's guidance. A comprehensive surgery assistance system is proposed as there are not many open-source systems that can support this technology. The system is capable of detecting the reference points placed on the body parts that will be operated on. Any movement of the reference points should be detected by this system, which would also alert the user with a message when movement is detected. This process is critical to ensure that the video images delivered to the remote monitor are identical to the video images captured in the operating room. Python version 3.9.4 was used, along with its associated libraries, to develop the proposed system. Socket communication using Transport Control Protocol (TCP) is used to make video transmission more secure. The proposed graphical user interface was accessed experimentally using the functional and reliability tests with the average percentage of 92% and 95% respectively to ensure that it was well implemented and both of the proposed goals were achieved.

Keywords: Graphical User Interface (GUI); video transmission; reference points analysis; movement detection; surgery

INTRODUCTION

Nowadays, telemedicine is widely used due to improved technology, which not only enables general practitioners to consult with specialists immediately but also enables ongoing knowledge transfer for medical assistants and trainee doctors. This is especially true for people who confront financial or geographical barriers to accessing adequate care. Telemedicine offers the ability to improve the effectiveness, organization, and accessibility of health care. Telephone-based treatment and telemonitoring of vital signs, for example, managed to reduce the risk of mortality and hospitalization while improving the quality of life in patients with heart disease (Haleem et al. 2021). The

specialist is not required to be present to ensure that the operation goes according to plan since remote visual communication will allow for monitoring and guidance during a surgical procedure. However, delivering real-time illustrations or annotations over streaming video is currently not feasible with current teleconferencing technologies. It would be ideal if these illustrations could also be placed right on the bodily parts that required surgery in the operation room (OR).

To address this gap, a three-part system is proposed that consists of a software application that allows users to sketch and send their drawings over live video conferences, a server computer in the OR that controls the video transmission, and a system that can project the drawing

directly onto the body part using projection mapping. For the purposes of this paper, the research will only focus on establishing a system at the server side in the OR that enables live visual communication between those involved in the surgery on-site and the specialist who will oversee and monitor the operation from a distance. It is undeniable that with the advanced growth of the internet and multimedia technologies, the medical profession, surveillance systems, and digital forensics are among the industries that have been employing a great amount of multimedia data in the form of audio, video, and images (Jan et al. 2020). This situation necessitates the development of a system capable of performing annotations on real-time videos remotely.

Additionally, a new motion detection system that can track the movement of physically positioned reference points that have been placed strategically throughout the region of interest will be added to this system. The research goal is to design a graphical user interface (GUI) at the server that enables visual communication from the OR and to develop a system that can detect the movement of reference points at our region of interest, are based on the development of these two systems.

Other parties will be in charge of developing the application that enables drawing during video conferences and sketching projection on a body part using projection mapping. The development and methodologies of telemedicine, data communication and its transmission in the medical field, image processing methodologies for image comparison and verification, as well as the software used for GUI development that uses image processing techniques have all been studied in order to provide a better direction for this research.

Sanjay Gandhi Post Graduate Institute of Medical Sciences (SGPGIMS) is one of the top telemedicine facilities in India that offers a variety of services such as a secure video conferencing platform, health database with information from India's medical network, servers that manage incoming and outgoing data transmissions, live streaming venues, and medical web portals (Chand et al. 2019) Due to its cutting-edge infrastructure and high-speed broadband connection network, the institute is able to provide those services. An Android-based application that enables diagnosis through remote consultation and the direct storage of health data in a database in the healthcare system is another example of telemedicine technology that has been developed (Prodhan et al. 2018).

The U.S. military is adopting telemedicine to modernize its monitoring systems, which are used to keep track of injured soldiers while they are out in the field, by utilizing ultra-broadband radio-frequency electronic cards. Data from the card will be transmitted directly to a database in the tactical communication network by scanning a QR

code with a mobile device. The Cross Domain Solution (CDS) will make sure that the transmitted data conform to the anticipated scheme. In the Medical Combat Data Cloud, which uses cloud computing to assure maximum privacy and security in the networking system, data is transmitted and stored through 4G LTE and Wi-Fi technologies (Bigott, 2018).

Personal Area Network (PAN) and sensor technology were utilised to develop a wearable health monitoring system utilising Arduino as the controller, using the same network as the Android-based application previously discussed. To link and view the data gathered by the sensor, a GUI was created. By using the Android software on the patient's mobile device, this data will be continuously transferred between the patient and the healthcare professional (Prodhan et al. 2018)

Among the researches done using image processing are studies that applies image processing techniques that focuses on the detection and segmentation of breast cancers (Curran et al. 2022) as well as the human spine (Halim & Huddin, 2022) using MRI images. To remove the area that touches the edges of the image while identifying the Region of Interest (ROI), the method of eliminating all objects discovered in the image's border is performed.

This system has an excellent accuracy rate (97.33%). A study was done to determine how effectively deep learning algorithms could identify feature points on radiological images of head profiles (Dobratulin et al. 2020). The system employed U-Net to track anatomical reference point results for each chosen neural network architecture and CNN to segment biological images. Each chosen neural network's anatomical reference point detection results will be compared to the actual anatomical reference points. As a result, using the CNN design for this segmentation process can produce results that are more accurate than those produced by an entirely conventional neural network while still processing data much faster.

The list of software used in earlier studies to develop GUIs that use image processing algorithms can be seen in Table 1. Due to its adaptability to integrate with other software and libraries, MATLAB has become a popular software option for past research in this field. However, Python software will be used to create the GUI and motion detection systems for this study since it is an open-source, has more comprehensible syntax, and enables simpler code comprehension.

In this study, the development of a reliable GUI and movement detection system is proposed to improve patient's access to health care and to optimize clinical staff efficiency as well as to combat clinical staff shortage, especially among rural area patients. The scope of this study is on the transmission of video feed from server to client, movement detection checking, and transmission of the feedback from client to server.

TABLE 1. Software used on past researchs for GUI development involving image processing

Author	Research Title	Software Used
Hanhan & Sangid (2019)	ModLayer: A MATLAB GUI Drawing Segmentation Tool for Visualizing and Classifying 3D Data	MATLAB
Ratanapakorn et al. (2019)	Digital image processing software for diagnosing diabetic retinopathy from fundus photographs	MATLAB
Cheng et al. (2019)	Apply computer vision in GUI automation for industrial applications	KORAT
Gui et al. (2020)	Visual Image Processing of Humanoid Go Game Robot Based on OpenCV	OpenCV-Python
Liu et al. (2020)	BrainSort: a Machine Learning Toolkit for Brain Connectome Data Analysis and Visualization	Python
Chiappini et al. (2020)	MVC1_GUI: A MATLAB graphical user interface for first-order multivariate calibration. An upgrade including artificial neural network modelling	MATLAB
Bardsley et al. (2021)	Matlab Software for Supervised Habitat Mapping of Freshwater Systems Using Image Processing	MATLAB
Jung (2021)	AniLength: GUI-based automatic worm length measurement software using image processing and deep neural network	Microsoft VB.NET
Zhuang et al. (2022)	AnatomySketch: An Extensible Open-Source Software Platform for Medical Image Analysis Algorithm Development	AnatomySketch
Misaki et al. (2022)	A Library for fMRI Real-Time Processing Systems in Python (RTPSpy) With Comprehensive Online Noise Reduction, Fast and Accurate Anatomical Image Processing, and Online Processing Simulation	Python
Mata et al. (2022)	MedicalSeg: A Medical GUI Application for Image Segmentation Management	MedicalSeg
Long (2022)	SPAMRI: A MATLAB Toolbox for Surface-Based Processing and Analysis of Magnetic Resonance Imaging	MATLAB

METHODOLOGY

A solution flow diagram for this project is depicted in Figure 1. The camera attached to the server computer will first capture the video of a patient's body parts in the OR, with reference points set on top of it to designate that area as the ROI or the image's focal point. By utilizing colour verification and image segmentation as a part of image processing techniques, the system will attempt to identify the reference locations.

Once this reference point has been located, its coordinates will be established and serve as a benchmark for comparing them to those in the following frame of images from the video that is been recorded. The reference points coordinates will be relocated if any differences were found between the coordinates of the first image frame and the following image frame received by the video. When differences in coordinates occurs, a "Movement Detected" error alert will appear, and the operation will restart and the same procedures will be performed again until no changes of reference point coordinates have been detected. Before the video transmission be transmitted to a remote device, the remote device must first establish communication with the server to ensure there is no change detected in the reference point coordinates.

The video streaming of the patient's body part will be continuously be supplied to the remote device after the server receives the feedback signal from the remote device as long as there is no movement from the reference points assigned. The specialist surgeon on the remote device side will then begin to sketch or draw necessary guidance on the real-time video in the form of annotation. On the server side, a projector device that is already connected to the server will then be projecting the extracted annotated data or sketches received from the specialist surgeon located at the remote device as shown at the end of the research flow. If the computer server does not receive any response from the remote device, the process flow will then be terminated.

With the concept that remote supervision would be performed from a device which could be managed by the specialist surgeon, this system was created to run on the server computer located in the OR. Therefore, all hardware required to support the real-time video streaming of the body part that has to be operated should be able to connect to this system. This system requires hardware components and software support to function properly and meet the research objectives. The hardware tools applied as research instruments are illustrated in Figure 2.

Python was chosen as the coding language since it offers the features of object-oriented programming, making

it simple to carry out the written functions by simply calling the existing object functions incorporated in Python library modules. GUI creation is one of the key areas of this research. In order to build this system, 14 Python library modules were downloaded all these library modules provide object functions that make it possible for our system to function properly. Version 3.9.4 of Python is the version that was used to develop the system's software.

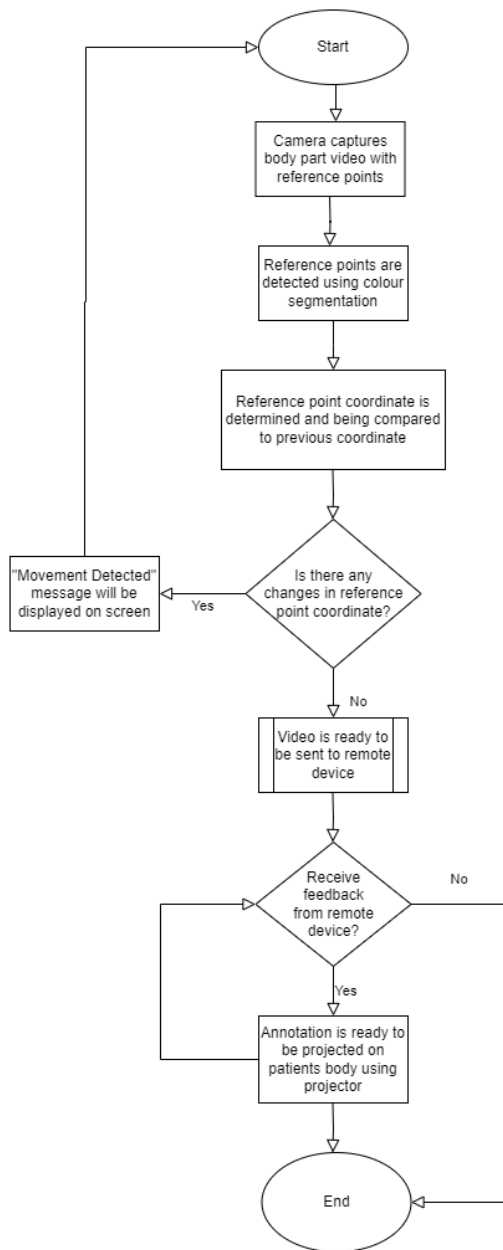


FIGURE 1. Research method flow diagram



FIGURE 2. Hardware devices used in research

Version 8.6 of Tkinter was used for this work. There are functions in another package called NumPy that can carry out mathematical or logical operations on more complicated matrix configurations or dimensions. Shell scripts or executable files may be called via subprocesses and OS library modules. Pickle and Struct modules allow smoother and better data transmission over the network.

The recognition of reference points and the detection of movement are the other components of the system that need to be developed. As a result, this research employs OpenCV software for image processing. There are many image processing tools available for use in OpenCV's large library. By calling the cvtColor command module from OpenCV, for instance, the process of changing the original image's colour can be accomplished. The Imutils library module has also been implemented since it offers several methods, including image rotation and image resizing routines, that are essential in image processing.

By using colour image segmentation approach, great segmentation accuracy can still be achieved even when applied to image regions with a very similar colour

(Jamaludin et al. 2018). In this study, a vivid green colour of the reference points was chosen to make them stand out when they were placed on top of human body components. Figure 3(a) depicts the actual hardware configuration settings while Figure 3(b) represents the block diagram of the hardware setup. The server on which we established all of the aforementioned systems is illustrated by the black laptop in the centre. The projector that can project the received image is connected to the camera that records the reference points. The silver laptop on the left represents the remote device used in this study.

In order to ensure the correct precision of the annotation region projected on the patient's body, it is essential that the reference point be correctly identified. As the study has been done, we believe that the duration

taken for the movement checking will not jeopardize the operation. Without this movement checking it may bring harm to the patient's body when the annotation is projected on the incorrect part of the patient's body.

When the server wants to transmit the video that was shot in OR, this laptop serves as the client, and sharing will only start if the client sends a signal confirming that a connection has already been established. For purposes of connecting the physical devices to the server as well as the visual communication between the server and client, a Maxis broadband network with a capacity of 30 Mbps was used. This study was done using a whiteboard and some reference points as a representation of the patient's body that will be applied later in the OR.

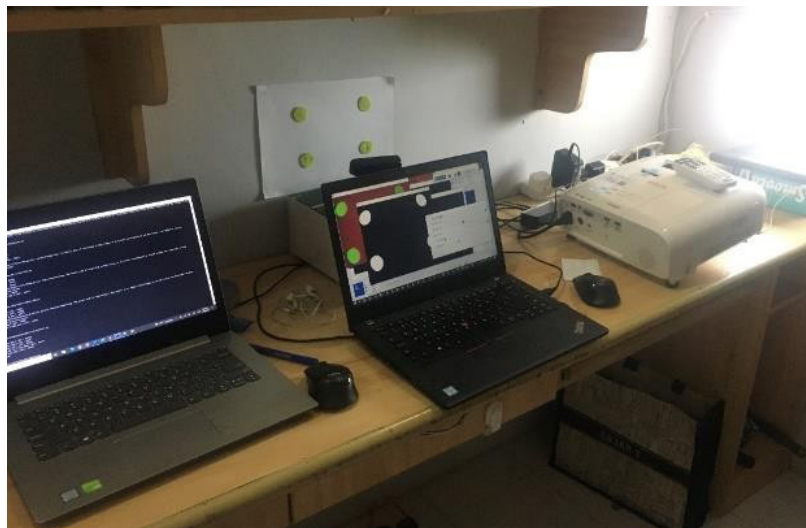


FIGURE 3(a). Actual hardware setup

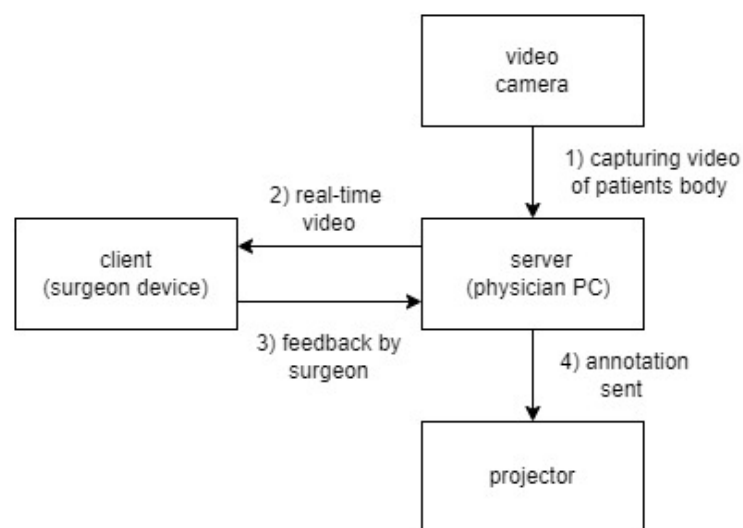


FIGURE 3(b). block diagram of the hardware setup

RESULTS AND DISCUSSION

There are three main categories that are being used to discuss the research outcome. The GUI development and its results are described in the first section. The video broadcast and its analysis are presented in the second section. The procedure of finding reference points is covered in the third section, and the final category to be covered in this topic is determining its coordinate. The functionality and stability of the systems generated as a result of this study are further tested, and the results are provided at the conclusion of this topic.

GUI DEVELOPMENT

The use of GUI is the most practical and user-friendly approach for users to carry out a procedure that has been programmed on the server computer in OR. In order for the staff in the OR to understand the system, the GUI design should be straightforward, intuitive to use, and simple. This GUI should also function in accordance with the way it was intended to and should complete processing shortly once a control button is pushed. Figure 4 represents the GUI result that was created for this study. In this GUI, the

Start Video Conference, Project Video, and Movement Checking buttons are the three key buttons. Each button is a representation of the action that will be executed when it is pressed.

The first button labelled “Start Video Conference” enables the server to transmit video to the client, a remote device that will later be used to monitor the surgery within the operating room. The second button, “Project Video,” enables the user to connect to a projector and project the received image using that projector. Setting for reference point verification can be done using the third “Movement Checking” button. The “-”, “□”, and “X” buttons are used to minimize window, maximize window, and close this GUI window, respectively.

The operating system’s command prompt window will also appear during the execution of a Python script, which is one of its characteristics. Since the GUI and all of the applications in this project were written in Python, this window could be viewed when the process is running, as seen in Figure 5. For some parties, like software engineers, this window can be hidden. For these parties, this window can provide a lot of information, such as feedback while the process is running and alerts if there are errors or when any interruption occurs.

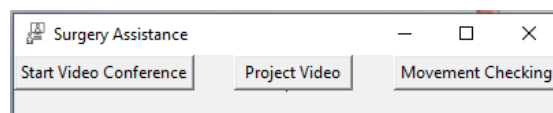


FIGURE 4. GUI developed at server in OT

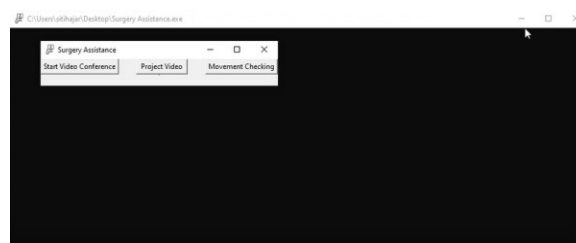


FIGURE 5. The appearance of OS Command Prompt during program execution

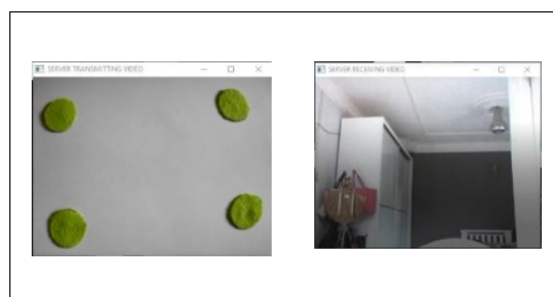


FIGURE 6. Video sent to the client (left) and video received from the client (right)

VIDEO TRANSMISSION

Undeniably, Information and Communications Technology (ICT) systems are becoming an essential component of ones daily life thus their integration into the synchrophasor network is vital (Yadav et al. 2022). Besides that, the Internet of Things (IoT)-based health remote support system includes networking, data processing, and application layer are gaining greater attention as a result of its capacity to cover several elements inside one system (Ahmad et al. 2022). As prior presented in the process flow, the system will begin when the “Start Video Conference” button is clicked. Before the server can send the image to the remote device, the procedure for comparing the coordinates of the reference point must be completed. This is done to ensure there hasn’t been any movement at the location of the reference points that can affect the accuracy of the annotation made using a remote device. When this requirement is fulfilled, a signal is transmitted to identify any remote device that is awaiting a connection to the server.

The process of transmitting live video from the OR will commence if the feedback signal is received, and the server will also be able to receive images or videos from the remote device, as shown in Figure 6. This process will stop and a warning will appear on the OS command prompt if no feedback signal is detected from any remote devices.

Since the communication takes place at the socket end point of these devices’ network connections, the communication between the server in OR and the client at our remote device is referred to as “socket communication” (Radhika et al. 2019). During the transmission process, the Transmission Control Protocol (TCP) is applied, and it only permits data transmission after a connection has been established between the server and the client through verification of the server computer’s IP address. Data communication between the server and client is done faster and more securely due to this protocol.

TCP was selected since it is the best effort protocol that allows two hosts to connect and establish communication while also providing a robust error-checking mechanism. The TCP protocol is also the most prevalent approach to carry out an internet connectivity framework, and it may retransmit dropped packets (Buenrostro-mariscal et al. 2023). Furthermore, TCP is utilised as the core of the message queuing telemetry transport (MQTT) protocol, which is one of the primary IoT applications, considering MQTT requires a protocol that delivers reliable and lossless bidirectional connections, such as TCP. While developing an IoT-based system, TCP sockets can be adopted as a low-cost and time-saving development environment (Boddy et al. 2019)(Ogur et al. 2022).

The server and client for this study have both been

connected to the same network. The same approach will be suggested for the system’s actual application. Since this technology is intended to support a surgical procedure, it should be expected that the information communicated between the OR and remote device is extremely private and confidential since it concerns patients’ privacy. The ideal option for a more secure data transmission procedure is by using a virtual private network (VPN), which is accessible by both server computers at OR and remote devices.

REFERENCE POINTS DETECTION AND COORDINATES SETTING

By clicking the “Movement Checking” button this will initiate the process of identifying reference points. The camera will acquire a reference point of the image, which will then be processed to create another HSV image. An image with hue, saturation, and brightness intensity values is known as an HSV image. HSV images are chosen for segmentation since they can be segmented more easily than other color information like YCbCr or RGB due to their different formats (Hema and Kannan, 2019). The HSV image dimensions are then divided, and a set of values are then assigned to each of them. In order to carry out image segmentation and determine the values of these three attributes, a track bar with the maximum and minimum ranges for hue, saturation, and brightness intensity is constructed, as seen in Figure 7.

As shown in Figure 8, the reference point is still not segmented properly as seen in the left image. As a result, the values on the track bar should be adjusted until the reference point image can be distinguished clearly as seen on the right image. These HSV values will be added to the program that is going to be executed when we click the “Start Video Conference” button after the reference point has been identified. This procedure must be followed whenever there are changes to the reference points, body parts of the patients, or in the operating room environment. This is due to the illumination in the OR, the location of the reference point, and the colour of the reference points. All these factors may have a significant impact on the HSV values.

The midpoint of one of the reference points will be selected as the reference coordinate once the reference point has been identified, as shown in Figure 9. When this coordinate is compared to the coordinates of the following image, a “Movement Detected” alert will appear when any position shift occurred at that coordinate (the value of δx or δy is not equal to 0), as shown in Figure 10. If any adjustments to this coordinate are made, either the reference points or the camera used to capture the image may have moved.

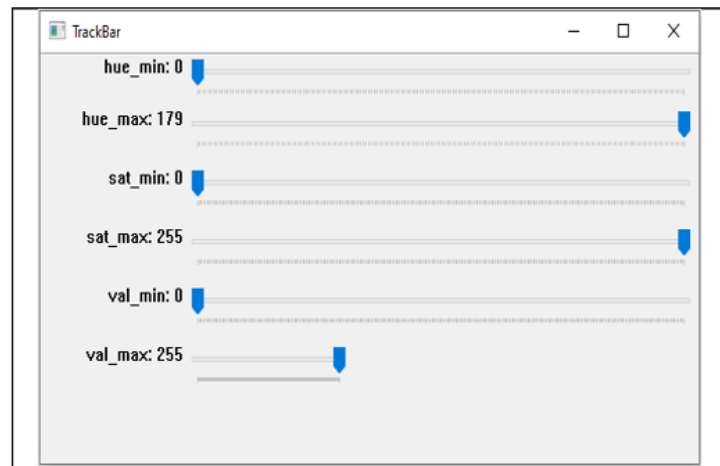


FIGURE 7. Track bar developed to determine the reference points image setting

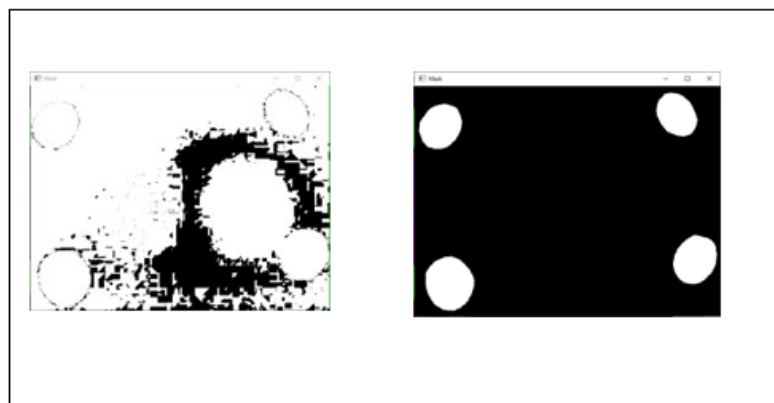


FIGURE 8. The process of setting the HSV value to clearly distinguish the reference point

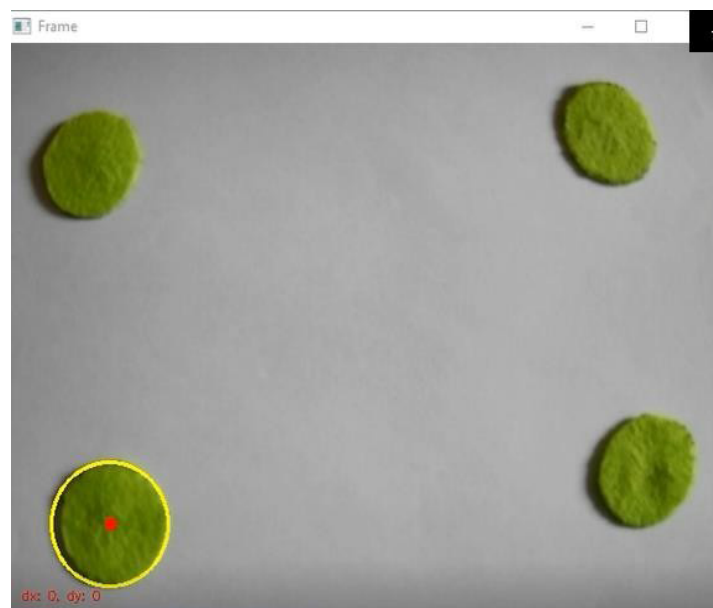


FIGURE 9. Process of determining the reference coordinates of a reference point

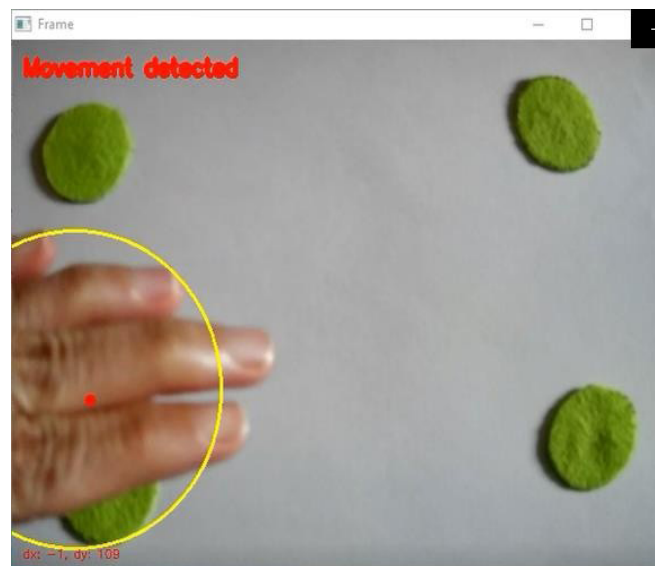


FIGURE 10. Showing of error warning

By making sure the camera is mounted properly, it is possible to physically fix the latter section such that any movement detected solely comes from the reference points. If this movement has already occurred, the system must wait until the warning interval is over before recapturing the image and moving on to the next phase, such as video transmission.

The systems that were successfully developed and proposed in the research objectives have completed a few tests to make sure they would perform as intended. The tests will examine the operation of the main processes used in this research, including the GUI, visual communication between the server and client, and motion detection. The proposed systems were put through three tests: a GUI functionality test, a network test while the video was being transmitted, and a motion detection effectiveness test. Since the study is still in preliminary phase, only limited number of iterations were performed to test the functionality of the network for the whole system.

FUNCTIONALITY TEST AND OUTCOMES FOR GUI

Once the GUI was successfully developed, a functionality test was conducted to ensure it can function as intended. The following are the test environments:

The system is tested by clicking on the SurgeryAssistance.exe executable file icon and GUI buttons.

1. During the test, no other programmes are running on the server machine.
2. The server computer is connected to all required hardware and the internet network specified earlier. The connections and all hardware are in fine working order.
3. Each button on this graphical user interface programme is pressed individually (not simultaneously).
4. In the same session, this functionality test was performed ten times in succession.

Table 2 displays the outcomes of this functionality test.

TABLE 2. GUI Functionality Test Result

Functionality Test	System can function accordingly (Yes/No)	Frequency
Pressing the "SurgeryAssistance.exe" icon	Yes	9/10
Pressing the "Start Video Conference" button	Yes	8/10
Pressing the "Project Video" button	Yes	10/10
Pressing the "Movement Checking" button	Yes	9/10
Pressing the "-", "□", "x" button	Yes	10/10

This study indicates that the GUI features can perform at least 80% of the time, with the average functionality test score of 92%. These results are sufficient to demonstrate that our GUI can function as intended and that our first goal has been achieved.

NETWORK TEST DURING VIDEO TRANSMISSION AND RESULT

To determine whether the video transmission can remain upon connection, the network will be terminated for ten

seconds during this test and then reconnected. The test will be repeated for ten times, where each client device and the server machine will alternately experience this network disconnection. This test was conducted in a single session, where only one device will be disconnected at a time. The test was conducted solely to determine whether the network will reconnect after network termination occurred. The network was reconnected upon termination within few seconds, that can be negligible. The network test results are displayed in Table 3.

TABLE 3. Network Test Result

Network Test	Can still continue video transmission? (Yes/ No)	Frequency
The network is disconnected at the server side for 10 seconds.	Yes	10/10
The network is disconnected at the client side for 10 seconds.	Yes	10/10

The results showed that even after the network had been down for 10 seconds, visual communication could still go on. However, if a network issue exists right away during the video transmission, this situation will completely change and it won't be put through all of this network test. The sole purpose of this test is to monitor the effects of the network level on video transmission. This conclusion will add to the system's reliability.

MOTION DETECTION EFFICACY TEST AND RESULT

The system's functionality to identify reference points, determine the reference coordinates, and issue a message if the coordinates were mismatched will be tested in the evaluation. This test was conducted under the following scenarios:

1. The environment setting, such as the lighting, hardware, and location of reference points, was identified in advance, and only this setup was used during this test.
2. In order to replicate the movement of the reference point, the necessary reference point is blocked. Also, the camera will be moved to investigate how camera movement influences error detection.
3. In order to measure the impact of moving other objects that are nearby the reference points, tools like combs and rulers have been moved between them.
4. Within the same session, this evaluation is done ten times.

Table 4 shows the outcome of the efficacy test.

TABLE 4. Motion Detection Efficacy Test Result

Efficacy Test	Can the process be done? (Yes/ No)	Frequency
Identify reference points	Yes	10/10
Determine the reference point's coordinate	Yes	9/10
Detect movements when reference points are covered	Yes	10/10
Detect movements when moving the camera.	Yes	9/10
Detect movements when moving other objects in between reference points	No	9/10
Show "Movement Detected" accordingly	Yes	10/10

It is evident from the result above that this system is capable of successfully identifying the reference points. The coordinates change permits the detection of movement for both the camera and the reference point, and if the movement of the reference point is detected, a warning message will be triggered. The system will not acknowledge the movement of the reference point if another object is moved in front of the camera until that object has entirely covered the reference point. It is safe to say that this motion detection system has accomplished what it was expected to do, and as a result, the study's second goal objective has been met.

CONCLUSION

The procedures and equipment discussed in earlier sections were used in order to achieve the research aims outlined for this study. As a result, the server computer designed to be installed inside OR successfully produced a GUI that permits visual communication. This system would provide video transmission between a server and a remote device in addition to controlling the live video capture of the body part in OR. Functionality tests were conducted to evaluate the system's reliability, and the findings show that the GUI can function at least eight times out of ten when the system is in operation. It is sufficient to derive from this conclusion that the GUI system can perform as intended.

A network test had also been carried out to determine whether the video transmission might still operate if the network had been disconnected for ten seconds at the server or client side. The outcome confirms that even after the server or client is restored to the network, the transmission can continue. This outcome will support our system's reliability even more.

A reference point analysis system should always be done to detect the movement of the reference point and issue a warning message when it actually happens in order to achieve the second objective. HSV image segmentation was used during image processing to determine reference points. After determining the location of the reference point, the reference coordinates at one of the reference points will be determined and compared with the coordinates of the accompanying image. If there is any difference in these coordinates or a movement has occurred at the reference points, then a "Motion Detected" warning will be presented.

This system has withstood a motion detection efficacy test, and the results show that the system is able to identify reference points, determine the reference coordinates, detect movement of reference points or cameras, and issue error warnings when a movement has taken place. It can be noted that this project's second objective has therefore been met with success.

A possible potential recommendation for this system is for it to be further integrated with other surgical assistance system components that have been studied and developed by other parties. Therefore, it is likely to eventually establish remote supervision with live annotation capability that can be projected directly on top of a body part. Not only will this revolutionise the field of remote surgery monitoring, but it can also be applied to academic discussions in class and meetings in a variety of industries, including engineering and education.

As previously noted in the GUI development section, the Python-based GUI has a tendency to display the OS command prompt window when executed, which may be bothersome to some users. Therefore, future studies into this issue using various language-based methodologies or tools may be relevant. More processes could run simultaneously with these enhancements if the hardware specs were enhanced, such as by increasing the RAM capacity on server computers to speed up programs processing. It is important to note that this study was done as a fundamental experiment where the system used is considered low-cost and widely used by various levels of users.

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DECLARATION OF COMPETING INTEREST

None

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