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Development of a Movable Telepresence Robot for Hospital Applications

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ABSTRACT—Mobile robotic telepresence is a relatively new area of study. The concept of telepresence has to do with the sense of being in a remote location when one is not there. This sense is made possible by all the technologies involved in enabling the person to have a feel of being remotely present and carrying out activities as if he/she were physically present. This research project work, therefore, aims to design and construct a telepresence robot with two visual perspectives that can be used for such applications as tele-ward rounds in a hospital as a part of telemedicine. Therefore, in this research, in addition to audio and video communication, the person will also be able to move around with the help of the mobile robot. Before now, we already have applications such as Zoom, Skype, WhatsApp video call and Microsoft team which affect telepresence and teleconferencing, but robotic telepresence adds the capability of transmitting action by actuating remotely via the telepresence robot. This is achieved by leveraging the existing telepresence technology applications. In this research project, we attempt to combine the load carrying capacity of autonomous robots used in hospitals with the telepresence ability of the telepresence robot. In addition, two views of the surrounding of the robot are obtained and observed by sharing the screen at the receiver end. The robot also has a measure of autonomy as it has a collaborative layer for obstacle avoidance. In general, this system with hybrid capabilities of telepresence, load carrying capacity, greater field of view and autonomous obstacle avoidance ability results in novel robotic telepresence for hospital use.

Keywords— Mobile Robotic Telepresence (MRT); Teleconferencing; Immersion; Telemedicine; Tele-surgery; Ambient Assisted Living (AAL); Digital Travel; Long-Term Care (LTC).

I. INTRODUCTION

Robotic telepresence as a new growing area of research has to do with the inclusion of a robot in the system of telepresence. The robot acts as a representative of the body of the remote user with requisite control and communication schemes. The concept of telepresence has to do with the sense of being in a remote location when one is not there [1]. This sense is made possible by all the technologies involved in enabling the person to have a feel of being remotely present and carrying out activities as if he/she were present. These activities include audio and video communication. However, in the case of robotic telepresence, in addition to audio and video communication, the person will also be able to effect movement with the help of the robot. Before now we have applications such as zoom, Skype and Microsoft team which affect telepresence and teleconferencing, but in telepresence robot, a greater dimension is added to the feel of being present by using a robot to represent the individual to be remotely present and the robot is being controlled accordingly by the individual who is the remote pilot. In general, robotic telepresence offers the means to connect to a remote location via traditional telepresence applications with the added value of moving and actuating in that remote location. [2]. There are often instances when remote presence is desired but not achieved and sometimes when achieved, it is not usually with the right effects. For instance, a doctor attempting to carry out ward rounds using zoom will not be able to interact more personally with his patients as he would have done if he were personally present in the hospital. With the telepresence robot, he can go from patient to patient attending to them personally as he is supposed to without the patient needing to operate any gadget or obtaining air time/data bundle for communicating with the doctor. This will be the major function of the robot in this research work. In addition, the robot will be able to travel with some required payload needed in the hospital environment. Furthermore, it would be capable of relaying other visual perspectives of its vicinity other than the primary perspective as required.

Telepresence for real-time face-to-face clinical consultation was first described in 1977 by Grundell et al. they experimented for six months using a two-way audiovisual system linking a private hospital and a large university medical centre. They discovered and recorded the following: (1) regular consultation in critical care can be provided. (2) telemedicine can be made available to users and providers. (3) the audiovisual link is superior to the telephone and (4) telemedicine can favourably influence the quality of care in a critical care unit. Many robots have been made to be autonomous by the application of artificial intelligence and such autonomous robots have been used to distribute supplies in hospitals, on the other hand, we also have telepresence robots whose function is to achieve telepresence for their users but in this work, we aim at developing a telepresence robot that would not only be able to achieve telepresence as the main goal of the most telepresence robot but also be able to act as carriers for essentials such as medicine and food with some level of autonomy by the collaborative layer included in its system. There is a growing need for technology to support remote participation in professional and personal activities due to crowded highways and airways and an environmental imperative to reduce fossil fuel consumption also the social distancing requirements due to the Covid-19 Pandemic. However with the surge in the development of internet technology; reduction in the relative cost of computers and improved manufacturing techniques, telepresence robots had witnessed substantial development in the last few years [3].

Robotic telepresence systems may be mobile or stationary depending on whether mobile or stationary robot is used. However, in this work, we focus on those robotic telepresence systems that are mobile. Kristofferson et al attempt to give an overview of Mobile Robotic telepresence (MRT)[4]. Mobility is a feature that makes the digital traveller able to virtually interact with others in a more seemingly real manner and able to demonstrate a relatively higher level of social interaction [5]. Various systems and application areas for such socially interactive robots exist. These include education and teaching, health and care for the elderly, entertainment, research, businesses and management[4].

Again, in the field of education telepresence robot holds great potential to make distance learning and teaching; even across national boundaries, more immersive through their ability to allow students to communicate with and navigate through remote educational environment[6]. Such robots become very useful in a situation where a student is ill and is unable to come physically to class, he can therefore be digitally present through the help of a telepresence robot. Similarly, a teacher can also be virtually present to teach his students through the help of a telepresence robot [7]. This approach to teaching and learning lifts the limits set by geographical distance, illnesses and order militating circumstances against physical contact in teaching and learning situations.

Telepresence robots have been utilized for several purposes having to do with social distancing and the need for personal presence. Telepresence robots have been utilized to solve the problem of social isolation and loneliness involving Old Adults and this is sometimes referred to as ambient assisted living (AAL) [8]. This can lead to very serious psychological disorders. [9]. However, there are some identified barriers to the use of telepresence robots in AAL situations. These include cost, privacy issues, internet connectivity, and workflow[10].

Application areas of telepresence robots are based on design. A comparative study of the characteristics of the various existing telepresence robot enables us to decide on the type of telepresence robot to use for a particular purpose. Yanco et al give a lucid description of various telepresence robots in terms of characteristics and applications [11]. This will enable a most proper choice for a particular use. An example of the importance of robot construction features concerning the use it would be put is seen in the work of Hector Aviles et al., the work focuses on identifying key features of the telepresence robot system in intensive care units in hospitals [12].

Smith, Mario Gregorio, and Lillian Hung applied a unique approach to the study of telepresence robots in a health care environment, the paper utilized the review methodology in which patients; health workers; researchers and students were involved in the research process which the aim was to assist in care for the aged and long-term care (LTC) settings which may lead to a state of depression and other complications including higher mortality rate. [13]. The result of the study is that it gives a summary of facilitators and barriers to the use of telepresence robots in mitigating social isolation and loneliness in older adults in care settings such as long-term care in hospitals.

It is hoped that shortly telepresence robots would become very versatile in many fields and especially in medical applications as a part of telemedicine [2][14][15]. The work of Chung et al gave an objective comparison of the various available telepresence robots for special uses and attempts to show the direction as per future research focus. To achieve more versatility in use, certain critical features must be considered and optimized for the particular application[4].

Material and Methods for the Development of a Mobile Telepresence Robot

In the design and construction of a telepresence robot, the approach is similar irrespective of the use to which the robot is to be put. The general idea is to replicate one's presence and the apparatus to achieve this must be capable of (i) Duplex communication in which the two ends can both transmit and receive communication signals simultaneously. (ii) Remote steering and control of the mobile robot that serves as the carrier for the communication gadgets. Various aspects of telepresence robots should be given attention if their performance, reliability, adaptiveness, and versatility would be enhanced. For Telepresence robots to meet the various needs and carry out the various tasks they may be required to do, we have to look into some critical factors that are central to their performance and reliability. There are several aspects to be looked into, these include the remote navigation system, the remote communication system, sensory and feedback of the system, and adaptively of the body framework design to conform to certain needs in a specific application such as medical application. Collaborative control is a scheme that is employed to enhance robot navigation and manoeuvring amidst obstacles.[16] The system with collaborative control can achieve autonomous steering where and when necessary to avoid obstacles or go through a narrow path when required. The paper focuses on developing a telepresence robot that would be used for various activities required by hospital staff, especially medical doctors, in the process of healthcare delivery in the light of the COVID 19 Pandemic. This would save the medical personnel the trouble and danger of physically coming in contact with patients having transmissible diseases before they could take care of them.

The project will consist of the hardware part (mechanical part and the circuitry) and software part; hence it is going to be an embedded system. The parts are as follows:

Mechanical part: The mechanical part is made up of the mechanical framework which serves as the skeletal support structure for the system and carrier for the various payloads the robot has to carry. It also gives the robot its general outlook. The material used for the structural design implementation is 1.5-inch PVC pipe with its joiners while the planes on the structure are covered by fibre HBF boards. The choices are informed by the mechanical and chemical properties of these materials.

Figure 1.0: Pictorial view of the structural framework of the robot robot

Electrical part: The electrical part is made up of the two savour motors for robot movement and the flexible power supply cables for the interconnection of the electrical, electronic, and microcontroller units.

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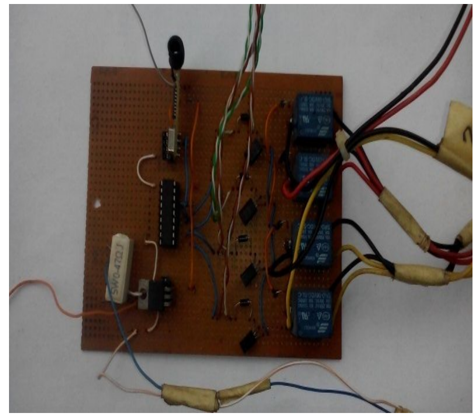

Figure 2:(a) savour motor (b) electronic control circuit board

Microcontroller: This is the main brain of the project. The code by which the robot will work is written onto it. The microcontroller used is ESP32. For RF signal communication, we need a transmitter and HD 12 D is used as the Encoder or transmitter and HD 12 E is used as the receiver or Decoder. ESP8266 is also incorporated into the collaborative layer to effect obstacle avoidance.

Figure 3: ESP8266 Micontroller

The range of signal coverage is between200m to 400m. Arduino UNO is also used as an adjoining microcontroller for coordinating the control commands from and to the hand-held remote control device. The codes for the transmitter, receiver and Atmega 328p Microcontroller in conjunction with the ultrasonic sensor are shown below:

International Journal of Advances in Engineering and Management (IJAEM)
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Demo 1 Transmitter Code

```
/*
  433 MHz RF Module Transmitter Demonstration 1
  RF-Xmit-Demo-1.ino
  Demonstrates 433 MHz RF Transmitter Module
  Use with Receiver Demonstration 1

  DroneBot Workshop 2018
  https://dronebotworkshop.com
*/

// Include Radiohead Amplitude Shift Keying Library
#include <RH_ASK.h>
// Include dependant SPI Library
#include <SPI.h>

// Create Amplitude Shift Keying Object
RH_ASK rf_driver;

void setup()
{
   // Initialize ASK Object
   rf_driver.init();
}

void loop()
{
   const char *msg = "Welcome to the Workshop!";
   rf_driver.send((uint8_t *)msg, strlen(msg));
   rf_driver.waitPacketSent();
   delay(1000);
}
```

Demo 1 Receiver Code

```
/*
  433 MHz RF Module Receiver Demonstration 1
  RF-Rcv-Demo-1.ino
  Demonstrates 433 MHz RF Receiver Module
  Use with Transmitter Demonstration 1

  DroneBot Workshop 2018
  https://dronebotworkshop.com
*/

// Include Radiohead Amplitude Shift Keying Library
#include <RH_ASK.h>
// Include dependant SPI Library
#include <SPI.h>

// Create Amplitude Shift Keying Object
RH_ASK rf_driver;

void setup()
{
   // Initialize ASK Object
```

International Journal of Advances in Engineering and Management (IJAEM)
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```
  rf_driver.init();
  // Setup Serial Monitor
  Serial.begin(9600);
}

void loop()
{
  // Set buffer to the size of expected message
  uint8_t buf[24];
  uint8_t buflen = sizeof(buf);
  // Check if the received packet is the correct size
  if (rf_driver.recv(buf, &buflen))
  {

    // Message received with a valid checksum
    Serial.print("Message  Received: ");
    Serial.println((char*)buf);
  }
}
```

Code for the obstacle avoidance scheme with ultrasonic sensor and Atmega 328p Microcontroller

```
/* Obstacle Avoiding Robot Using Ultrasonic Sensor and Atmega 328p Microcontroller
 *  Circuit Digest(www.circuitdigest.com)
 */
int trigPin = 9;      // trig pin of HC-SR04
int echoPin = 10;     // Echo pin of HC-SR04
int revleft4 = 4;       //REVerse motion of Left motor
int fwdleft5 = 5;       //ForWarD motion of Left motor
int revright6 = 6;      //REVerse motion of Right motor
int fwdright7 = 7;      //ForWarD motion of Right motor
long duration, distance;
void setup() {

  delay(random(500,2000));   // delay for random time
  Serial.begin(9600);
  pinMode(revleft4, OUTPUT);      // set Motor pins as output
  pinMode(fwdleft5, OUTPUT);
  pinMode(revright6, OUTPUT);
  pinMode(fwdright7, OUTPUT);

  pinMode(trigPin, OUTPUT);         // set trig pin as output
  pinMode(echoPin, INPUT);          //set echo pin as input to capture reflected waves
}
void loop() {
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);     // send waves for 10 us
  delayMicroseconds(10);
  duration = pulseIn(echoPin, HIGH); // receive reflected waves
  distance = duration / 58.2;   // convert to distance
  delay(10);
    // If you dont get proper movements of your robot then alter the pin numbers
  if (distance > 19)
  {
    digitalWrite(fwdright7, HIGH);                    // move forward
```

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 8 Aug. 2022, pp: 1638-1647 www.ijaem.net ISSN: 2395-5252

```
  digitalWrite(revright6, LOW);
  digitalWrite(fwdleft5, HIGH);
  digitalWrite(revleft4, LOW);
 }
 if (distance < 18)
 {
  digitalWrite(fwdright7, LOW); //Stop
  digitalWrite(revright6, LOW);
  digitalWrite(fwdleft5, LOW);
  digitalWrite(revleft4, LOW);
  delay(500);
  digitalWrite(fwdright7, LOW);     //movebackword
  digitalWrite(revright6, HIGH);
  digitalWrite(fwdleft5, LOW);
  digitalWrite(revleft4, HIGH);
  delay(500);
  digitalWrite(fwdright7, LOW); //Stop
  digitalWrite(revright6, LOW);
  digitalWrite(fwdleft5, LOW);
  digitalWrite(revleft4, LOW);
  delay(100);
  digitalWrite(fwdright7, HIGH);

  digitalWrite(revright6, LOW);
  digitalWrite(revleft4, LOW);
  digitalWrite(fwdleft5, LOW);
  delay(500);
 }
}
```

Other onboard electronic circuits: These include a voltage divider circuit and switching circuit to operate the relay via the switching transistors or driver. These work in conjunction with the microcontroller, ESP32 and Arduino microcontroller to control the robot as desired by actuating the wheels according to commands received.

Ultrasonic sensors: These are to enhance the robot's mobility with obstacle avoidance.
Phone screen or mobile device: this would be the 'head' of the robot where the video of the guest appears. Also, the audio/video signals are received and transmitted via the tablet's microphone, speaker, camera and screen. For greater productivity, a wireless speaker can be connected via Bluetooth connection to the tablet.
Wireless speaker: A wireless speaker is used as the audio output device in conjunction with the phone.
Adjustable phone holder: This is a mechanical rod with provision for position adjustment.
The whole system is made into modules such that. Each separate module can be detached independently without affecting other parts of the robot. This approach simplifies construction and in the event of any technical fault, troubleshooting would be simple as the fault is easily localized and fixed. The array of the individual stages to give rise to the whole system is illustrated in Figure 4.

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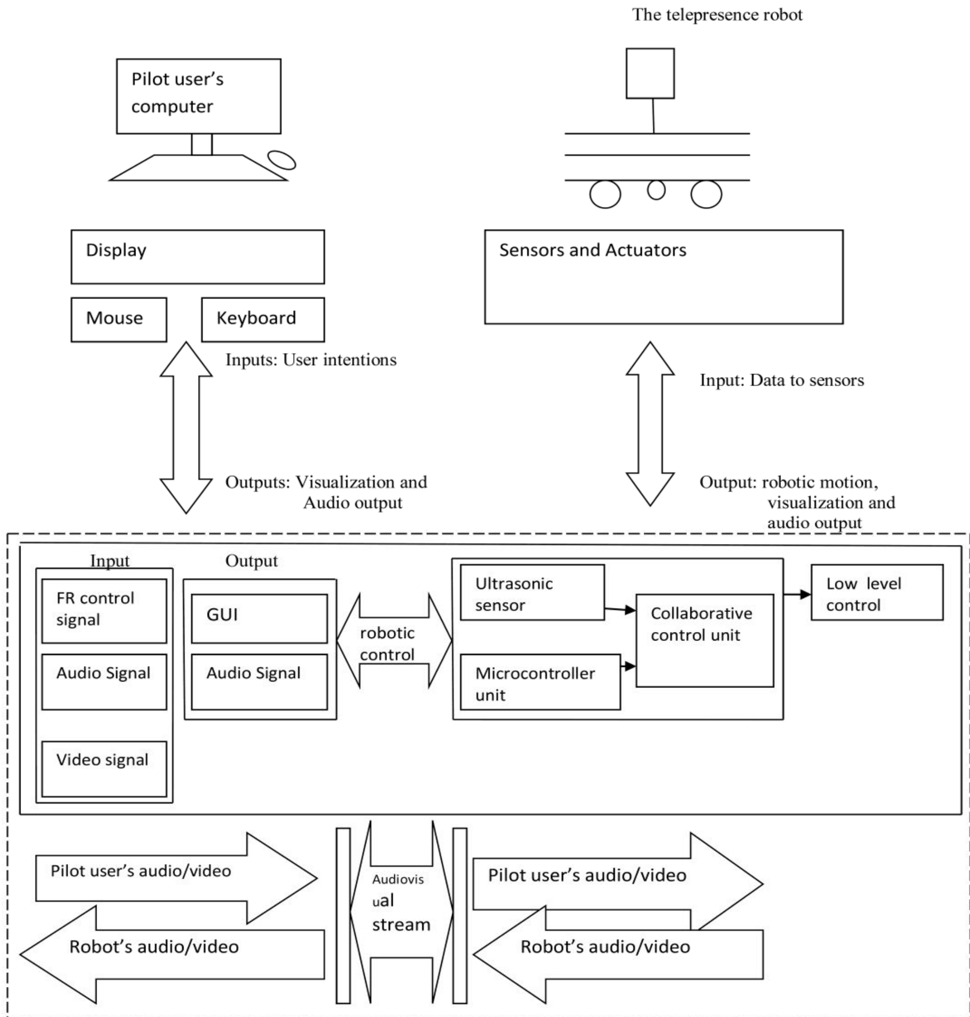

Figure 4: Overall architecture of the considered robotic telepresence application

The collaborative control combines information from the user's intentions and sensory data to guide the robot to the destination marked by the user, while automatically negotiating obstacles. The block diagram shows the various stages involved in the process from the visitor's side to the robot and from the robot to the visitor's side.

The visitor's side is equipped with input and output transducers such as a screen display; camera; mouse; and keyboard also there is a graphical user interface for smoother real-time interaction and control. The audio, video and control signals are processed at the visitor's device by the device application and then transmitted through the appropriate channel to the telepresence robot which receives the signals, displays the video and gives out the audio. The telepresence robot has a collaborative layer module. The aim of this is to give the robot some level of autonomy and to enable it to collaborate with the control system in navigation and obstacle avoidance. That is when a control command is given and the direction of the command has an obstacle' the robot can autonomously avoid such using fuzzy logic. In the same way that signals are sent to the telepresence robot from the visitor's end, audio and video are sent to the visitor by the telepresence robot [4].

Also, the weight of the robot must be made as light as possible. But this possesses a challenge as the robot has a payload of the circuitry plus the tablet (or screen). To solve this problem the body frame of the robot is made of very light material. More also

attempts were made in the design to lower the centre of gravity of the robot to enhance its stability giving it a stable equilibrium as possible.
Given the multimedia communication required of the robot, a 4G LTE module is incorporated to ensure seamless data transmission and skype is used as the telepresence application employed.

Software

The software to be used is c-programme. This is because c-programme is very versatile especially when it comes to an embedded system. C-programme is used extensively for Arduino and other microcontrollers. More also, it is easily used to diversify the usage of adjoining hardware. The programme is written based on an algorithm that depicts the expected behaviour of the robot in stated situations. The coding is carried out bearing in mind the possibilities of unforeseen constraints and eventualities so that amendments and upgrading of code are easily carried out without needing to start the coding from scratch in such circumstances. This way the reliability and relevance of the software are maintained with time.

Test, Result and Discussion

The system was developed bearing in mind the necessity of combining teleoperation ability with load carrying ability. Also, the robot was made to have two 'heads' to improve the field of view and perspective of interaction with the pilot user. These qualities were tested after the robot was developed with the conceived aim and objectives. The robot successfully combined teleoperation with load carrying. The average speed for the teleoperator to keep track of the system communication was 0.5m/s and the load carrying capacity for normal operation at this speed was found to be 20Kg. As for the audiovisual/control synchronization; the time lag depends on the teleconferencing application used and the signal strength of the communication network used at the time. However, the lag can always be compensated for by slowing down the rate we send the control signals to synchronize with the communication signal.

The double 'head' of the robot resulted in two perspectives of the vicinity of the robot being available to the pilot user. These perspectives were the front and the rear views. The two views were successfully received by partitioning the screen of the receiving gadget at the pilot user's end.

II. CONCLUSION

In this work, a unique approach to the development of a telepresence robot has been adopted. Generally, the concept of a telepresence robot is just the incorporation of the common telepresence scheme into a mobile robot. By this, we will not only be able to transmit and receive audio and video signals but also we will be able to actuate the mobile robot remotely, the robot thereby representing its pilot user at the remote location. To enhance the versatility of the robot a carrier is incorporated and a second 'head' is also used to increase the field of view consequently the pilot can view two perspectives on the receiver screen achieved by screen partitioning. These improve the sense of digital travel effect. The developed system satisfactorily functioned as expected in terms of its audiovisual/control synchronization, load carrying capacity and visual field enhancement. However, there is still a time lag between the audiovisual signal and control signal' which impairs the needed sense of immersion desired for optimum performance of the system. Hence communication protocol is a potential aspect of future research to mitigate the time lag challenge and enhance seamless digital travel via the system.

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