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Human Machine Interface for Dexto Eka: - The Humanoid Robot

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Abstract— **This paper illustrates hybrid control system of the humanoid robot, Dexto:Eka: focusing on the dependent or slave mode. Efficiency of any system depends on the fluid operation of its control system. Here, we elucidate the control of 12 DoF robotic arms and an omnidirectional mecanum wheel drive using an exo-frame, and a Graphical User Interface (GUI) and a control column. This paper comprises of algorithms, control mechanisms and overall flow of execution for the regulation of robotic arms, graphical user interface and locomotion.**

Keywords—exoskeleton; robotic arm; omni direction; control column; graphical user interface

I. INTRODUCTION

Robots are no longer a part of science fiction or man's imagination, they are a reality. And the era of humanoid robots has dawned. Most contemporary scientists have chosen humanoids as their source of intrigue. This paper portrays the human machine interfacing of Dexto:Eka:, the humanoid robot. This robot has been created with the ultimate aim of achieving tele-presence. Dexto:Eka: has been conceptualized to work in three modes: dependent, semi-sovereign and sovereign. In the dependent the tele-operator has complete control over the robot, whereas in the semi-sovereign mode, although the tele-operator retains control over the robot, it can choose to ignore a command should it prove detrimental to its well-being. The robot retains autonomy over its actions in the sovereign mode [1].

Dexto:Eka: has arms of 6 degrees of freedom and an omnidirectional locomotion drive. The arms have been mounted on a dowel-like structure attached to the backbone of the robot. The torso and kilt give it the appearance of a human [2]. The robot body of the robot has been fabricated from aluminum, thus making it lightweight. The master-slave system of Dexto:Eka: is implemented using two At mega 2560 microcontrollers[3] one of which acts as master and the other as a slave. Communication between them is enabled via a Wi-Fi channel.

This paper focuses on the dependent mode of Dexto:Eka: which enables tele-operation through the Human Machine Interface(HMI). The HMI comprises of an exo-frame to control the arms of the robot, a control column which governs locomotion and graphical user interface to perform multifarious activities.

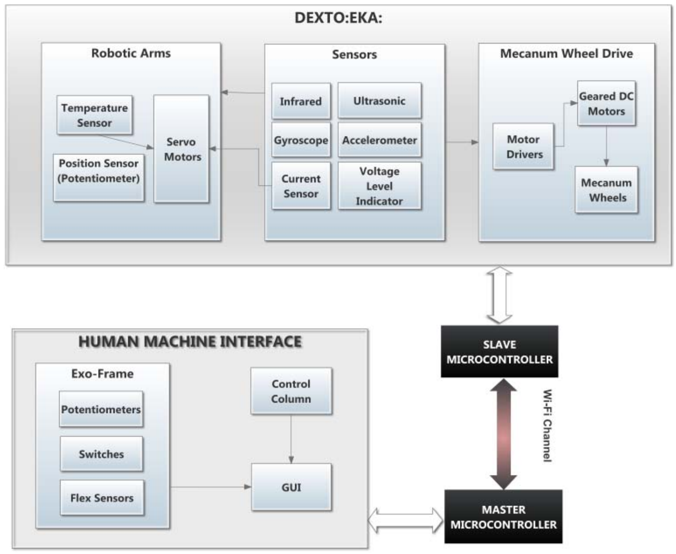

Fig. 1. Control Diagram of Dexto:Eka:

II. RELATED WORK

The robot presented in [4] is similar to Dexto:Eka: but is smaller in size. Computer aided software has been used to control the robotic arm seen in [5]. This is time consuming and less accurate. So to overcome this we developed an exo-frame which allows efficient motion of the arms and also gives an improved sensation of teleportation. The use of inverse kinematics as seen in [6] does not solve the problems of accuracy; this problem was also solved by exo-frame.

Robot arms with mimic motions are used in applications such as in telemedicine such as in endoscopy and in various surgical purposes [7]. But in all these projects which use extensively the use of tele-presence for surgical purposes [8], the surgeons face a plenty of problems regarding precision and vibrations in the arm during surgeries. Implementation of a proportional integral derivative (PID) control mechanism helps to minimize such vibrations in the arm and generates a smooth motion of the arms.

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A biped robot, though an interesting option was not chosen mainly because of challenges in balancing [9].Using wheeled locomotion also saves time to move around in complex places, as it takes minimum space to move around even less than a biped robot.

Development of Graphical User Interface in [10] gives only the values of the angles of the actuators used in the arms, but our GUI enables other function like calibration, values of the safety sensors used, further the values of current and temperature sensors which make it easy to judge the proper functioning of the robot.

III. Exo-Frame

A. Design

Sometimes unexpected situations may occur that cannot be pre-programmed into the system. Hence, we developed an exo-frame for such unforeseen circumstances. Exo-frame maps the actions of the tele-operator on to the actuators and restricts the motion of the operator's arm to the same 6 DOF that can also be performed by the anthropomorphic robotic arm. The exo-frame has been equipped with potentiometers that measure the extent of motion of the tele-operator's arm. The data is then sent to the master microcontroller which in turn processes it and forwards the data to slave microcontroller via Wi-Fi. And then the servo motors receive the data from the slave microcontroller.

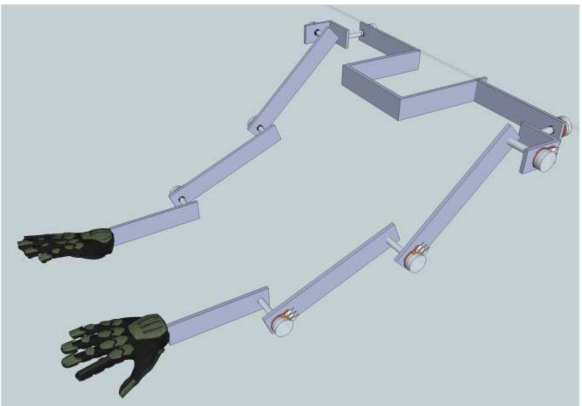

Fig. 2. Diagram of the exoframe

B. Control

The above mentioned exo-frame is used to mimic the motions of the operator onto the robotic arm and control the 6 DOF of each robotic arm namely:

- Shoulder: Abduction-Adduction
- Shoulder: Flexion-Extension
- Elbow: Flexion-Extension
- Wrist: Flexion-Extension
- Wrist: Circumduction
- Gripper: Open and close

Further, a proportional-integral-derivative (PID) method of control [11] was implemented in the program itself so as to get precision in positioning and to reduce shudders in the arm.

The master microcontroller implements the algorithm in Fig. 3 whereas the slave implements the algorithm in Fig. 4 thus implementing the effective emulation of human arm by robotic arm.

```
procedure MIMIC()
1: //Read values obtained from potentiometers of exo-frame
   W    ← analog_read (P0)
   E    ← analog_read (P1)
   S    ← analog_read (P3)
   A    ← analog_read (P2)
2: //Map from 0-1023 range to required angle range
   W    ← map(W,0,1023,-90,90)
   E    ← map(E,0,1023,0,120)
   S    ← map(S,0,1023,-40,90)
   A    ← map(A,0,1023,0,105)
3: //Gripper and pivot control using digital input from push buttons controlled by teleoperator
   P    ← digital_read (B1)
   G            ← digital_read (B2)
4: if P is HIGH do
5:      rotate_clockwise;
6: else do
7:              rotate_anticlockwise;
8: endif
9: if G is HIGH do
10:     open_gripper;
11: else
12:     close_gripper;
13: endif
14: end procedure
```

Fig. 3. Mimic algorithm for master microcontroller

```
procedure Slave_MIMIC()
1: //Write values transmitted from master onto Actuators
        write(GServo, G);
        write(PServo, P);
        write(WServo, W);
        write(EServo, E);
        write(SServo, S);
        write(AServo, A);
2: //Write values onto Mecanum Wheel Drive
        write(wheel, direction);
3: end procedure
```

Fig. 4. Mimic algorithm for slave microcontroller

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As stated above, a PID mechanism is implemented in the governing algorithm and servo motors have inbuilt PID controllers [12]. So having two PID controllers helps in achieving better precision and control with limited or negligible vibrations. Closed loop feedback mechanism is used in control of the arm and can be seen in Fig. 5.

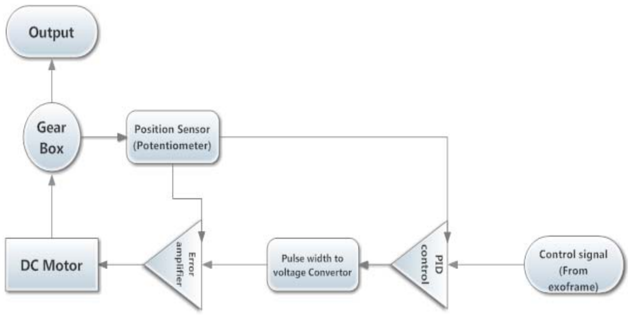

Fig. 5. Closed loop feedback mechanism

IV. CONTROL COLUMN

A. Design

The locomotion drive of Dexto:Eka: is made omnidirectional using mecanum wheels[13]. The resultant force from all the wheels determines the direction in which the mecanum wheel drive would move as seen in figure 6. The omnidirectional mecanum wheel drive of the robot is controlled using a control column which works similar to a joystick [14]. It has 2 potentiometers representing the x and y axis and 5 push buttons. This is a shield that can be easily connected to the microcontroller and is easy to operate.

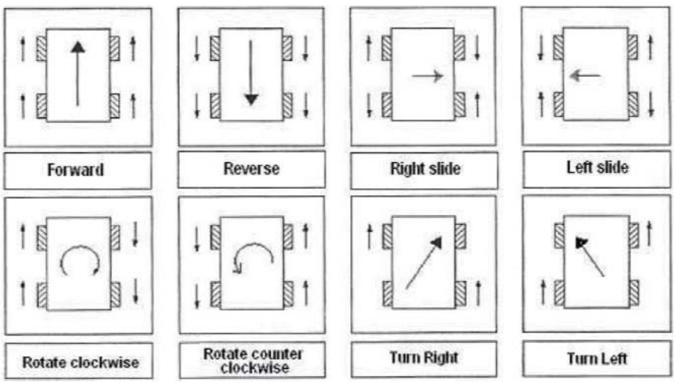

Fig. 6. Different motions of four mecanum wheels

B. Control

The potentiometers generate analog signals upon movement. The data is then sent to the master microcontroller which in turn processes it and forwards the data to slave microcontroller via Wi-Fi which is finally sent to motor drivers in form of PWM signals to control the speed and direction of motors [15].

The motion of the joystick is mapped onto the mecanum wheel drive using the algorithm in figure. 7.

```
procedure Control_Column()
1: //Read the values of the potentiometers of the joystick.
        X       ←anolog_read(x);
        Y       ←analog_read(y);
2: //2 motor drivers A & B control 4 motors
3:  // Forward Motion
    if X is 0 && Y is 0 do
4:      inp1A=HIGH, inp2A=LOW;
5:      inp3A=HIGH, inp4A=LOW;
6:      inp1B=HIGH, inp2B=LOW;
7:      inp3B=HIGH, inp4B=LOW;
8: // Backward Motion
    else if X is 1023/2 && Y is 1023/2 do
9:      inp1A=LOW, inp2A=LOW;
10:     inp3A=LOW, inp4A=HIGH;
11:     inp1B=LOW, inp2B=HIGH;
12:     inp3B=LOW, inp4B=HIGH;
13: //Movement in right direction
    else if X is 1023/4 && Y is 1023/4 do
14:     inp1A=HIGH, inp2A=LOW;
15:     inp3A=LOW, inp4A=HIGH;
16:     inp1B=LOW, inp2B=HIGH;
17:     inp3B=HIGH, inp4B=LOW;
18: //Movement in left direction
    else if X is 3*1023/4 && Y is 3*1023/4 do
19:     inp1A=LOW, inp2A=HIGH;
20:     inp3A=HIGH, inp4A=LOW;
21:     inp1B=HIGH, inp2B=LOW;
22:     inp3B=LOW, inp4B=HIGH;
23: // move diagonally top right
    else if  0<=X<=1023/4 && 0<=Y<=1023/4
do
24:     inp1A=LOW, inp2A=LOW;
25:     inp3A=HIGH, inp4A=LOW;
26:     inp1B=HIGH, inp2B=LOW;
        inp3B=LOW, inp4B=LOW;
27: // Similar mapping is done for 3 remaining diagonal motions as well
28: end procedure
```

Fig. 7. Algorithm for mecanum wheel drive

V. GRAPHICAL USER INTERFACE (GUI)

A. Design

The Graphical User Interface (GUI) seen in Fig. 8 has been designed prioritizing ergonomics and simplicity [16]. A new user can easily control the system with ease. Complete operation of robot can be done using the GUI. It also enables

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monitoring of activities of robot. It depicts the motion of the robotic arms in the form of bar graphs. Data retrieved from the sensors is also shown on the GUI. A radar-like interface illustrates the motion of the robot. This GUI is made using Processing, a java based software.

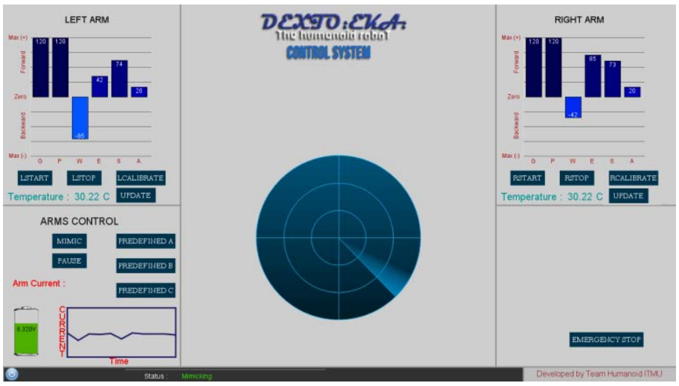

Fig. 8. Graphical User Interface

B. Control

The basic working of the GUI has been characterized in fig. 9 and its functioning is governed by the algorithm in fig. 10.

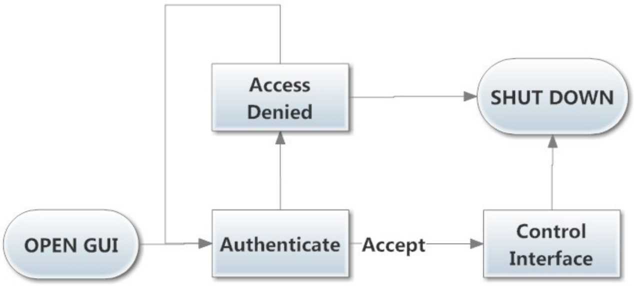

Fig. 9. Block Diagram Of GUI

```
procedure GUI()
1: while (true)
2:      master_read(arm_data)
3:      plot(bar, arm_data);
4:      master_read(arm_temperature)
5:      //Send Control Input
        //(start/stop/calibrate etc.) to master
6:      display(status)
7:      master_read(battery_status)
8:      draw(battery-indicator);
9:      master_read(arm_current)
10:     plot(line, arm_current)
11: end while
12: end procedure
```

Fig. 10. Algorithm for GUI

The control interface is the heart of the GUI which comprises of all aspects of the governance of the robot. The display is divided into segments for control of each arm, locomotion using radar like interface, overall arm control and basic control mechanism. This can be seen in fig. 11.

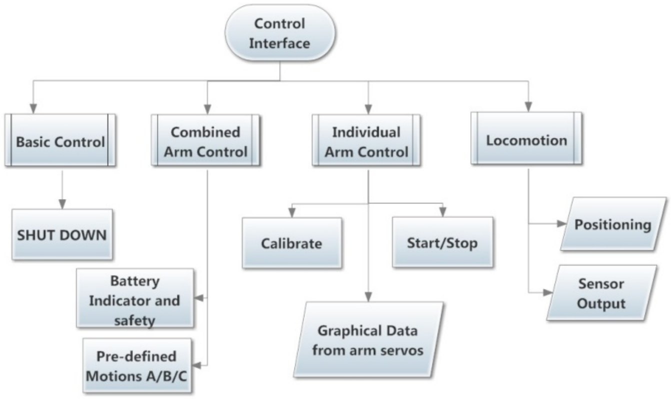

Fig. 11. Functions of GUI

C. Functions of GUI

1) Calibration

Initial positions of the exo-frame may vary depending on the physical structure of teleoperator adorning it. Hence, there is a need for regulation of preliminary values before execution of mimic function. Initial values of the exo-frame are read when the calibrate button is pressed.

```
procedure Calibrate()
1: while(true) //for each joint
2:      val = analog_read(potentiometer) //read
values of potentiometers at joints
3:      val = map_to_angle(val)
4:      servo_write(val)
5: end
```

Fig. 12. Algorithm for calibration

2) Start/Stop

Arm movements can be individually initiated or terminated as per user requirement.

3) Status Bar

A status bar at the bottom of the screen constantly displays the current activity being performed by the robot.

4) Graphical Data From Arm Servo

The positioning of the arms is dynamically represented in the form of bar graphs. Feedback is obtained from the servo motors is mapped into angles which are then plotted using the algorithm in (13).

```
procedure armGraph()
1. while(true)
2.      master_read(arm_data)
3.      plot(bar, arm_data)
4. end
```

Fig.13. Algorithm for plotting graph

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5) Predefined Motion

There are buttons on GUI for choosing the mode of operation and switching between three different predefined motions of the robot.

6) Battery Indicator

Any value below 6.8V would be detrimental to the functioning of robot. Hence a battery indicator in the GUI constantly shows battery status. The battery regulator is determined by table 1.

TABLE 1: BATTERY STATUS

Voltage (Volts)	Battery Percentage (%)
9-8.44	100
8.44-7.40	75
7.40-7.20	50
7.20-7.00	20
7.00-6.80	5
<6.80	BATTERY IN PERIL

D. Security Features Of GUI(Sensors)-

Sensors act as interface between the environment of robot, its actuators and the user. Sensor generates analog voltage values by sensing the physical quantity they are designed for.A temperature sensor will send voltage signal because of change in resistance due to change in temperature. This makes temperature sensor a interface between its servos and environment. Dexto:Eka: is equipped with variety of sensors like ping ultrasonic sensor, IR sensor, Temperature sensor, current sensor, gyroscope etc. All these are important part of Dexto:Eka: with each sensor being installed after keeping in mind the utility of robot. These sensors continuously send data to slave microcontroller which is then transmitted to master microcontroller via Wi-Fi [17] and output is displayed on GUI. User can monitor this and operate robot accordingly. Moreover these sensors are responsible for actions of robot in semi-sovereign and sovereign mode.

1) Temperature Sensor

One wire digital temperature sensor in installed on both arms of Dexto:Eka: whose output value is displayed on GUI and if temperature rises above a particular limit which may harm the wiring or any other part of structure of the robot then it automatically abandons that task.

2) Ultrasonic And IR Sensors

Alternate ping ultrasonic sensors and IR sensors are mounted on the chassis of Dexto:Eka:, which helps the robot to map the surrounding environment and traverse safely. The ultrasonic sensors perpetually provide the distance from any obstacle and improve accuracy in distance measurement. These sensors enable smooth locomotion in sovereign mode.

3) Gyroscope

A more advanced and important module installed on the head of the robot so as to balance it on rough terrain [18]. The module senses any deviation from the normal position of the backbone. It sets the speed of the motors of the locomotion according to the degree of the backbone from its original position.

4) Current Sensor And Battery Protection Circuit

High current or low voltages level may harm the motors or other components installed on the robot. That is why it is necessary to keep track of values of these quantities and if values of current exceeds the given limits then high current rated MOSFET installed helps in shutdown of robot and algorithm is made in such a way that no harm is cause to the robot and a button is also provided on GUI if it is required then user may shut down from his workplace. Same is case of the low voltage; if battery gets discharged the battery protection circuit helps in shutdown of robot using relays.

VI. EXPERIMENTS

A. Robotic Arm

Tests were conducted on control of robotic arms in slave mode (mimic operation) with the help of exo-frame. Initial experiments had shudders in robotic arms which were removed by implementation of PID algorithm in control algorithm of arm and efficient calibration of exo-frame. Mimic operation can be seen in Fig. 14.

Fig.14. Mimic operation of robotic arm

B. Graphical User Interface(GUI)

Every joint is calibrated prior to mimicking operation. The functioning of GUI was tested to ensure smooth operation and bugs and errors that due to coding were subsequently removed. The Graphical User Interface perpetually refreshes its display in order to display updated data.

VII. CONCLUSIONS AND FUTURE WORK

This paper is an excellent example of how tele-presence can be achieved using a using a human machine interface. Various experiments on the exo-frame showed excellent results of tele-operation. PID control implemented on exo-frame

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works perfectly and has helped in removing shudders which were there in arm before its implementation. Future work includes development of the sovereign control system for Dexto:Eka: which would be purely dependent on sensor output and image and audio processing techniques.

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