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Wireless motion controlled dual six axis robotic arms with rover

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ABSTRACT

A robot is a machine, which is designed to carry out a complex series of actions either automatically or controlled manually by using remote device. The objective of this project is to design a wireless motion controlled dual six axis robotic arms with rover using motion technology. This robot can be used in national defense system, for border surveillance, repair works in critical areas, mine detection and diffusing. In this work concluded, the robot is designed and assembled in such a way that all the operations can be carried out by using only hand motions along with push buttons.

1. Introduction

It is fact that during the wars of Iraq and Afghanistan, robots are killing America's enemies and saving the life of American soldiers. The future generation of "war-bots" will be immensely more advanced – said by Singer, P [9]. There are many methods which are used to control robotic arm by using different sensors, some of them are using Flex sensor [10], Vision-based hand-gesture [11], Accelerometer-based control [12] and using the leap motion controller [13]. From gone through literature, mostly the researchers investigated about single robotic arm and their controlling methods are complex. Hope that no one proposed any statement for controlling double robotic arm where human work is needed like assembling of parts in industries and bomb dismantling.

This project is designed in such a way that it can be remotely operated with a motion capture joystick to carryout complicated work at any situation. The robot got two independent motion controlled6-DOF arms which make tough jobs easier to do. All the operation of the robot can be controlled using a joystick equipped with motion detection sensor, which makes it easier to control. The controlling device of this robot is designed to replace the suitcase type controller, which makes it lot easier to carry.

The two individual motion controlled arms, in which each arms has 6 DOF can perform a way better than the single arm with traditional controlled robot. These robots can be used to perform highly complicated works where human like actions are required to accomplish the required job, and to conduct surveillance and operations in highly critical areas.

2. Proposed model

The model consists of two receiving and two transmitting units. The first transmitting unit is the joystick which is used to control the 6-DOF dual robotic arms with rover by using hand motions.

The second unit consists of one receiver and transmitter which is used to extend the range of operation in open space up to 1 km by receiving data through 433 MHZ RF receiver and transmitting it through the NRF24L01+ with the help of ATmega328P microcontroller.

The third unit is the receiving end which consists of NRF24L01+, ATmega328P microcontroller for controlling servo and dc motors. The servo motor is used for the arm motion which is controlled by the servo controller by receiving the data from ATmega328P microcontroller. The whole arrangement is placed in a mobile platform with wheels for wireless remote operations. The Fig. 1 below clearly explains the whole process which is involved in this system from the joystick to the robot (see Table 1).

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Table 1
Specification of dual six axis robotic arm with rover.

Specifications	Value
No. of arms	2
DOF of first arm	6 DOF
DOF of second arm	6 DOF
Min servo angle	0°
Max servo angle	180°
Range of operation in open space	1 km
Motion sensor used	GY-9250 MPU

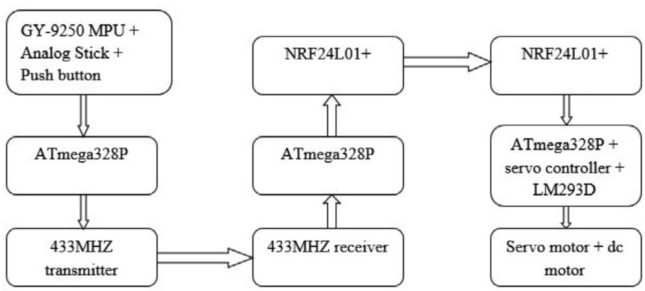

Fig. 1. Flow chart of process.

3. Methodology

3.1. Joystick

The MPU-9250 Nine-Axis MEMS Motion Tracking Sensor is mounted in the joystick to detect the angle of roll and pitch motion of the joystick along the X and Y axis. The microcontroller acquires the value from the MPU and Analog stick in analog form. The push buttons in the joystick outputs digital values to the microcontroller. The combined output of MPU, analog stick and push buttons are used to generate the final output which is required to control the two robotic arms and the rover. The final output which is then transmitted to the hub with the help of 433 MHZ RF transmitter. The Fig. 2 block diagram of joystick explains the working of joystick.

The joystick is programmed with three modes to control the robot. They are arm-1 mode, arm-2mode and driving mode. In arm-1 mode the joystick transmits data to control right arm of the robot, in arm-2 mode the joystick transmits data to control left arm of the robot and in driving mode it transmits data to control the mobile platform of the robot. Joystick uses gyro sensor of the IMU to capture rotational motion of the joystick in all the modes. The Fig. 3 shows the completed and working model of the joystick. The "□" and "O" key are used to switch between arm-1 and arm-2 modes. The "△" key is used to reset the position of both the arms in their default position and the "X" key is used to turn "ON" and "OFF" the joystick. Finally the middle button in the analog stick is used to switch between arm and driving mode. The analog stick is also used to control the mobile platform.

Fig. 3. Joystick in power off state.

The Fig. 4 shows the Orientation of Axes of the MPU in the joystick along the X, Y and Z axis. In which the gyro sensor of the MPU is used to detect the roll and pitch Orientation of the joystick along X and Y Axis. The −X value of the gyro sensor i.e. below −5 is used to move the servo 1 in forward direction by incrementing the PWM values of the servo 1, the +X value of the gyro sensor above +5 is used to move the servo 1 in backward direction by decrementing the PWM values of the servo 1. Like that the Y axis value of the gyro sensor is used to control the PWM values of the servo 2. The combined output of Orientation of Axes of the joystick along with the push button data is used to control other servos in the arm.

The Fig. 5 below shows the visual identification of three modes of the joystick. The Fig. 5(a) shows the visual identification of ARM-1 mode (right arm mode), (b) shows the visual identification of ARM-2 mode (left arm mode) & (c) shows the visual identification of motion controlled driving mode.

3.2. Hub

The operating frequency of RF transmitter and receiver is 433 MHZ and the operating range in open space is 100 m. The hub circuit is designed in such a way to increase the range of operation of the rover in open space by adding a NRF24L01 2.4 GHZ PA + LNA SMA wireless transceiver in its circuit. It uses 2.4 GHZ global open ISM band, with license free and it can extend the range of wireless communication up to 1 km in open space. The NRF24L01+ automatically re-sends lost packets and generate acknowledge signal, which ensures the strong communication

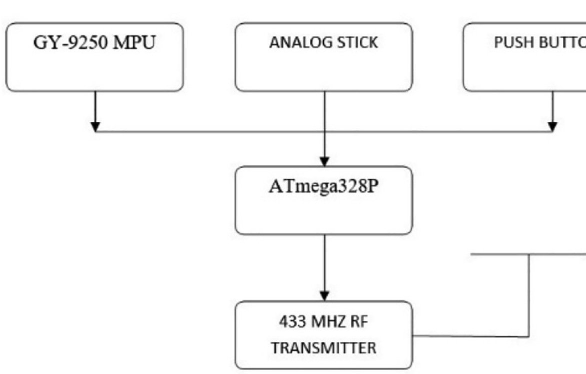

Fig. 2. Block diagram of joystick.

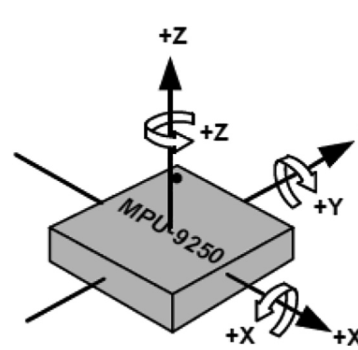

Fig. 4. Orientation of axes [4]

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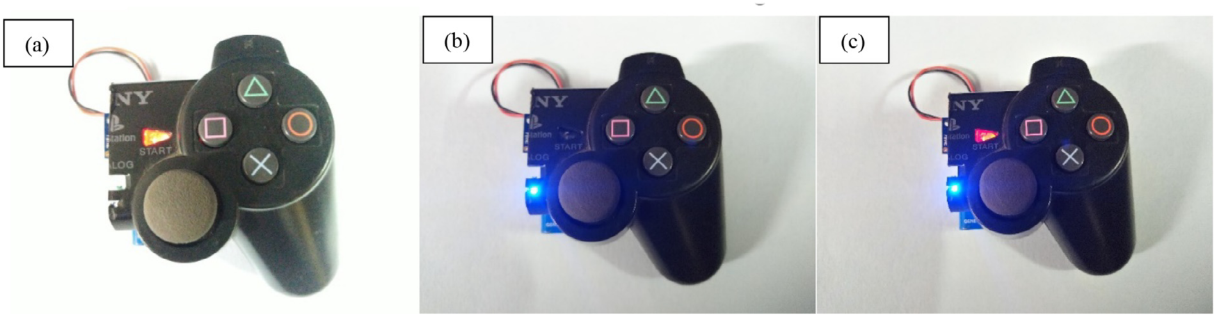

Fig. 5. (a) Arm-1 Mode (Right arm controlling mode); (b) Arm-2 Mode (Left arm controlling mode); (c) Motion controlled driving mode.

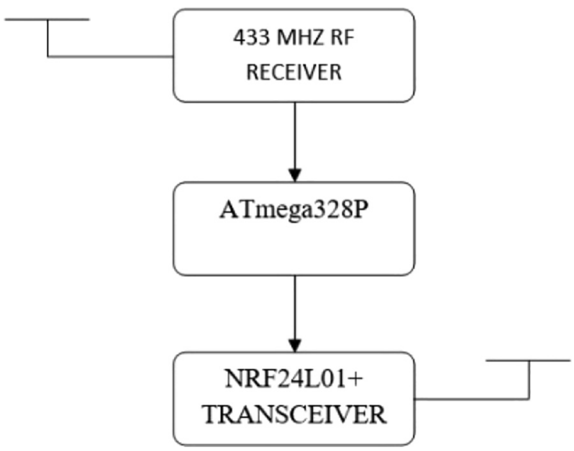

Fig. 6. Block diagram of hub.

between the hub and the rover. The Fig. 6 below, block diagram of hub explains the working processes of the hub.

The ATmega328P microcontroller in the hub receives the data through the 433 MHZ RF receiver and transmits it through the NRF24L01 2.4 GHZ PA + LNA SMA wireless transceiver in order to extend the range of operation in open space. The Fig. 7 shows the completed and working image of the hub.

3.3. Rover

The ATmega328P microcontroller in the rover receives the data, which is transmitted by the hub through NRF24L01+ transceiver and produces the output to the 16-channel 12-bit servo controller and LM293D by comparing the received data with the preprogrammed data within the microcontroller. The Fig. 8 block diagram of the rover below explains the complete operation and working of the robot from receiving the data through NRF24L01+ and converting it into a mechanical work through servos and DC motors. The robot can be wirelessly controlled over 1 km in open space. The rover uses a 6 V 4.5 Ah lead acid battery to power the servo and dc motors. The microcontroller, NRF24L01+ transceiver and the dual H-bridge motor driver IC is powered using two 3.7 V li-ion batteries.

The 16-channel 12-bit servo controller is connected to the Atmega328P microcontroller through i2c protocol. The servo controller controls all the 12 servos of the 6 DOF dual arms according to the data outputted by the Atmega328P in the rover.

The LM293D IC is responsible for the motion of rover in the open space. The LM293D is a bidirectional DC motor controller, which can be used to drive two DC motors simultaneously. The LM293D controls the rotating direction of dc motors accordingly to the data outputted by the Atmega328P microcontroller in the rover. The Fig. 9 below shows the completed and working image of the robot with 6 DOF dual robotic arm in mobile platform with wheels in operating condition. The Fig. 9 (a) shows the front view, (b) shows the side view and (c) shows the top view of the robot.

4. Literature review

4.1. GY-9250 MPUa

GY-9250 MPU module is used to measure the angle of roll and pitch of the joystick using 3-axis gyroscope. This module provides

Fig. 7. Hub.

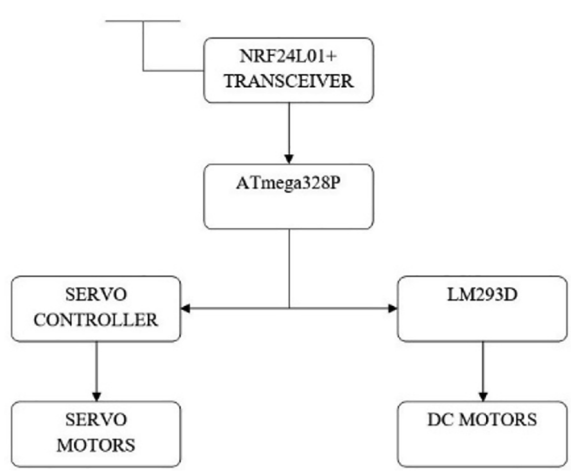

Fig. 8. Block diagram of rover.

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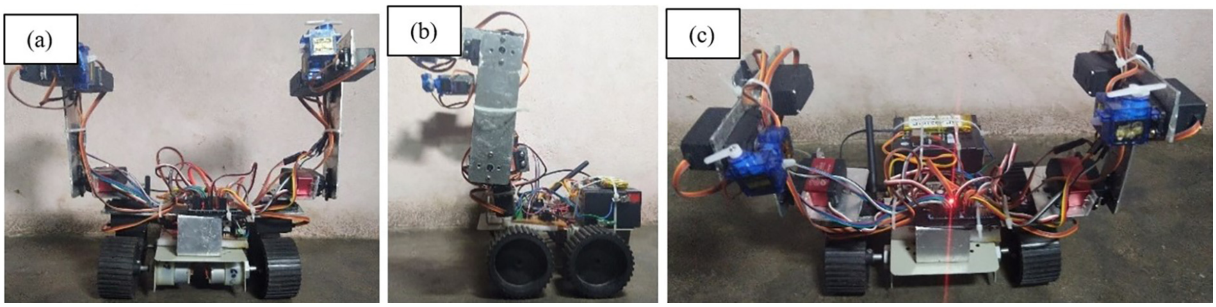

Fig. 9. (a) Front view of rover; (b) Side view of rover; (c) Top view of rover.

i2c communication protocol, which make it easier to connect with ATmega328. The full scale range of gyro sensor is ±250, ±500, ±1000, ±2000 and rate noise is 0.01. The operating voltage of the sensor is 2.4–3.6 V [4].

4.2. ATmega328P

The ATmega328 is a single-chip microcontroller which is created by Atmel in the megaAVR family. ATmega328P is an 8-bit AVR RISC-based microcontroller combines 32 kb ISO flash memory with read-while-write capabilities. It has 23 general purpose I/O pins, 32 working general purpose registers and three flexible timer/counters. It supports i2c, SPI and USART protocols [1–3].

4.3. 433 MHZ RF transmitter and receiver

It features low power consumption (typ 11 mA) and very stable operation frequency. The operating frequency is 433 MHZ and the range of operation in open space is 100 M. The operating voltage of transmitter is between 3 V and 6 V and receiver is 5 V [5]. This transmitter is used because of its low power consumption and compact size transmitter which easily fits inside the joystick.

4.4. NRF24L01 2.4 GHZ transceiver

It uses 2.4 GHZ global open ISM band, with license free. The range of communication in open space is 1 km. It features SPI interface communication with MCU I/O port. The transmit power of NRF24L01 2.4 GHZ Transceiver is greater than +20 dBm. The 2 Mbit/s speed makes high-quality VoIP possible [6].

4.5. F16-Channel 12-Bit servo controller

The 16-channel 12-bit servo controller used to control the position the arm by controlling all the servos individually. 16 servos can be controlled using this module. The operating voltage of the servo controller is 5 V. It features a i2c communication which makes it easier to connect it with microcontroller with only two wires [7].

4.6. LM293Da

LM293D is a dual H-bridge motor driver IC. Two DC motors can be driven simultaneously using this IC, in both forward and reverse direction. The supply voltage for the IC is 5 V. The supply voltage for motor is 9–36 V. The input logic 00 or 11 will stop the corresponding motor. Logic 01 will rotate the motor in clockwise and 10 in anticlockwise direction respectively [8].

4.7. Servo motor

The two arms in which, each arm consist of 6 servos. There are three different variants of servo motors are used in the arm. They are

- SR-6120MG
- SG90 9 g micro servo
- MG996R

The SR-6120MG is a 20 kgcm torque 4.8–6.8 V digital servo, which is used both arms for shoulder tilt motion to lift the arm and the pay load. The SR-6120MG is used as Servo-1 in both arms.

The SG80 9 g is a 3–3.5 kgcm torque mini servo motor used in both arms for the end effectors. The SG80 9 g is used as Servo-5 & 6 in both arms.

The MG996R is a high torque 10 kgcm stalling torque servo motor which is used in all other joints of both the arms. The other servos i.e. Servo-2, 3 & 4 in both the arms are MG996R servos.

5. Applications

5.1. Military

Motion controlled dual 6-DOF robotic arms with rover can be used to do critical jobs in borders. It has two individual motion controlled arms which makes the job easy while comparing single armed traditional controlled robots. These robots can also be used for surveillance and operations in highly critical areas.

5.2. Research

These robots can be used to handle highly radioactive and hazardous substance which humans can't handle. It can be also used to explore dangerous location where humans can't directly visit.

5.3. Space

These robots can be used to perform critical operations in space. Going outside the shuttle to repair damaged parts is a life threatening job for astronauts; instead these robots can be used as it is motion controlled and it has dual independent arms.

6. Result

The dual 6-DOF robotic arms with rover are controlled using a motion capture joystick and the desired result is achieved. The output combination of motion sensor along with the push button is used to produce data, which is used to control the robot. Thus easy and efficient way of controlling a 6-DOF robotic arms with rover controlled using a motion capture joystick is implemented.

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The user operation of the joystick and the motion of the arms and rover is tabulated below. The analog stick in the joystick is also used to drive the rover.

6.1. ARM-1 Mode (default mode)

(see Table 2)

Table 2
Arm-1 mode.

Roll and pitch motion of joystick along the axis	Push button pressed	Motion of the arm
Along negative X axis	–	Arm-1 Servo-1 in positive direction
Along positive X axis	–	Arm-1 Servo-1 in negative direction
Along negative Y axis	–	Arm-1 Servo-2 in positive direction
Along positive Y axis	–	Arm-1 Servo-2 in negative direction
Along negative X axis	R1	Arm-1 Servo-3 in positive direction
Along positive X axis	R1	Arm-1 Servo-3 in negative direction
Along negative Y axis	R1	Arm-1 Servo-4 in positive direction
Along positive Y axis	R1	Arm-1 Servo-4 in negative direction
Along negative X axis	R2	Arm-1 Servo-5 in positive direction
Along positive X axis	R2	Arm-1 Servo-5 in negative direction
Along negative Y axis	R2	Arm-1 Servo-6 in positive direction
Along positive Y axis	R2	Arm-1 Servo-6 in negative direction

6.2. ARM-2 mode

(see Table 3)

Table 3
Arm-2 mode.

Roll and pitch motion of joystick along the axis	Push button pressed	Motion of the arm
–	"□"	Enters into arm-2 mode
Along negative X axis	–	Arm-2 Servo-1 in positive direction
Along positive X axis	–	Arm-2 Servo-1 in negative direction
Along negative Y axis	–	Arm-2 Servo-2 in positive direction
Along positive Y axis	–	Arm-2 Servo-2 in negative direction
Along negative X axis	R1	Arm-2 Servo-3 in positive direction
Along positive X axis	R1	Arm-2 Servo-3 in negative direction
Along negative Y axis	R1	Arm-2 Servo-4 in positive direction
Along positive Y axis	R1	Arm-2 Servo-4 in negative direction
Along negative X axis	R2	Arm-2 Servo-5 in positive direction
Along positive X axis	R2	Arm-2 Servo-5 in negative direction
Along negative Y axis	R2	Arm-2 Servo-6 in positive direction
Along positive Y axis	R2	Arm-2 Servo-6 in negative direction
–	"O"	Exits from arm-2 mode

6.3. Driving mode

(see Table 4)

Table 4
Driving mode.

Roll and pitch motion of joystick along the axis	Push button pressed	Motion of the rover
–	Centre joystick button	Enters into motion controlled driving mode
Along negative X axis	–	Rover moves in forward direction
Along positive X axis	–	Rover moves in backward direction
Along negative Y axis	–	Rover moves in left direction
Along positive Y axis	–	Rover moves in right direction
–	Centre joystick button	Exits from motion controlled driving mode

6.4. Other operations

(see Table 5)

Table 5
Other operations.

Roll and pitch motion of joystick along the axis	Push button pressed	Motion of the rover
–	"△"	Resets the position of both arms to default position
–	"X"	Turns "off" the joystick
–	"X"	Turns "on" the joystick

Conclusion

This approach can be used in areas, where more precise, complicated and work like human is required to accomplish the work. The motion capture joystick provides a better way to control dual robotic arms in a natural way hence no special trainings are required to operate. The two individual robotic arms replicates the human hand, hence two motion capture joystick can do the work lot easier, faster and efficient. Wireless cameras can be used to get live feedback from the robot to accomplish long distance operations. FPV camera with 5.8 GHz, 40 channel video transmitters can be used to transmit video up to 1.5 mile (2.4 km).

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