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Research Article

The Design and Construction of an Industrial Mobile Robot

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Abstract: This project is aimed at the design, control, and operation of a mobile robot intended for industrial applications.This project is a redesign of an existing work with features added to meet the current trend in robotics and in computer networking. A completely mobile robot with more sensors was achieved. A previous work on robotic arm was analysed with a view of improving it and meeting the limitations encountered (Insufficient motor torque, Heavy robot weight, six degrees of freedom failure, and Lack of flexibility in the entire system). Through Research, these limitations where met. Other Achievements Included the useof encoders and decoder at transmission and reception ends, and the use of printed circuit boards (PCB).Although this project was cost-intensive, time-consuming, and brain-tasking;our mobile robot (JUDCOM1) which was once fiction is now a reality, thanks to the Art of Electronics. Robots like this find application in Auto-manufacturing industries, Electronic manufacturing industries, Power/Energy industries, Health-care industries, aeronautic and aviation amongst several others.
Keywords: Computer, Encoder and Decoder, Motor, PCB (Printed Circuit Board), Robot, and Sensors.

INTRODUCTION

This project is aimed at the design, control, and operation of a mobile robot intended for industrial applications. Robotic systems are composed of both hardware and software components. The hardware and software components of a robotic system are interfaced through the design and construction process. The interfacing is carried out in such a way that the hardware component can interact with the physical/immediate environment and at the same time, the response or behaviour of the robot can suitably be controlled using a controller which is software based. Sensing and actuation are the physical ports through which the "Controller" of the robot determines the interaction process of its mechanical part (physical body) with the physical world (external environment). Figure 1 illustrates how the components of a robotic system are interconnected and also how interact with the physical environment.

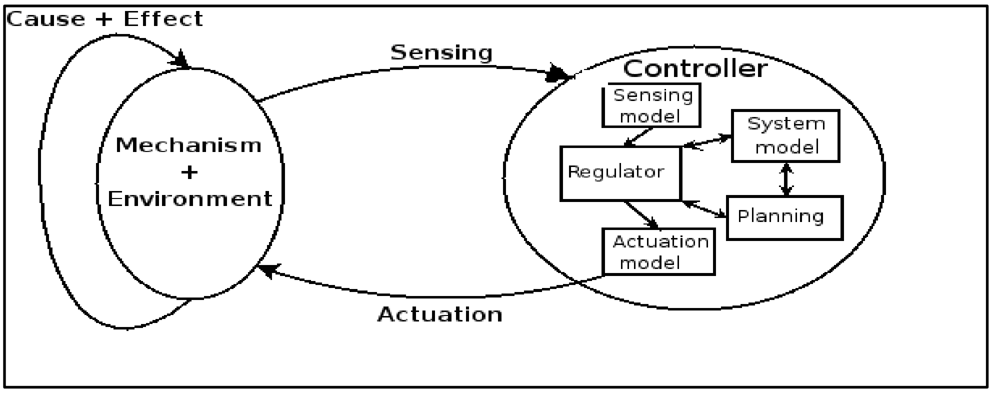

Figure 1: Robotics depicted as an integrated control system relating with the physical environment

Application of Robots/Robotics

Industrial Application:

Most robots used for industrial applications are stationary, mobile or the autonomous robots. Robots are mainly used for automation and simulation purposes. Different industries apply these different robots for different purposes as highlighted below:

- Auto-manufacturing industries use robots in their car plants for Welding, Spring Painting, Assembly Operation, Dispensing Operation, Laboratory Operation, Palletizing and Material Holding.
- Electronic manufacturing industries apply stationary robots in the production of ICs (Integrated Circuits) and other circuit components.
- Power/Energy industries apply robots especially in nuclear power plants for visual monitoring of processes where ordinarily is hazardous to man.
- Health-Care industries now apply robotics in many operations. For instance, certain surgical operations can be remotely performed using the Da Vinci surgical robot machine, x-ray imaging machine etc.
- Robots have become very useful and are widely applied in many aeronautic and aviation applications. Examples include robotic flight simulation, automatic robotic flight control in military war planes, NASA space exploration robots etc.

Experimental Application:

Robotics has gained ground in many experimental applications. These applications range from biological, chemical to military. For example:Aquatic robot for the study of aquatic life, Micro Ant-robots to aid studies intended to break new grounds in entomology (the study of insects), Aero-robots for study of rare species of birds etc.

Human Assistants (Domestic Application):

Mobile-Autonomous robots are widely used as personal assistance to physically deformed humans. These robots perform a wide range of activities all geared towards rendering some form of help to the user. Example: opening a door, typing documents on a computer, switching on/off electronic devices.

Entertainment:

A newly found use of robots is in the area of entertainment. Some robots are designed specifically to play musical instruments by simply simulating a human musician. This is gaining popularity in Japan, U.S, and China etc.

Military Application:

The United States had once boasted of being capable of sponsoring a human-free combat war fare. A 21st century standard of modern war fare were humanoid robots would replace human soldiers; robotic pilots would be used in place of skilled pilot, aero robots would serve as spies etc.; and in the end a high level of efficiency would still be obtained. Truly, the future holds the birth of a new type of war fare where robots will completely replace humans.

RESEARCH METHODOLOGY

Electrical and Electronic Components

A research was carried out into DC Motors, Stepper Motors, Microcontroller with AT89S52 beingconsidered the best available microcontrollers that can satisfy the requirements of this project, RF Transmitter/Receiver Pair, Encoder/Decoder Pair, Motor Driver, Buffers, Battery, and the parallel port [1-3].

Mechanical Design of the Mobile Robot

A research was done in selecting Materials, Designing the Chain System, and Locomotion. This influenced the decisions about what materials and construction techniques that we considered appropriate for our design and implementation. Before we started to build, we looked up specifications in suppliers' catalogues and used logical design practices in the layout and construction of our robot.

The communication system

A block diagram of the communication system for the robot is shown in figure 2.

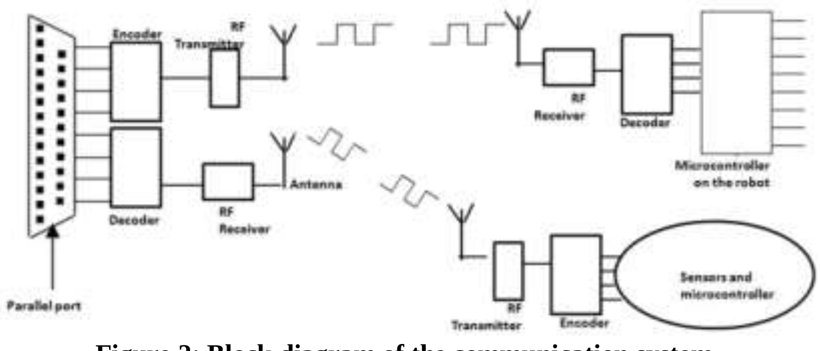

Figure 2: Block diagram of the communication system

Most robots use electrical signals for communicating with the servos and motor speed controllers; they differ in how they deliver that information from the control circuit to the robot. Most robots use a single radio frequency channel or infrared to transmit the control information from the transmitter to the receiver. To deliver information to drive multiple servo channels, the servo pulse information is transmitted serially, one pulse following another on the radio signal. The transmission of control information between the transmitter and the receiver is usually sent as radio waves in one of two different ways: AM or FM.

The radio modules often used for communication transmit AM radio signals. This is because FM systems, though more efficient, are too complex and expensive to construct. However, encoder/decoder chips are meant to flush out any data stream that does not pass the Cyclic Redundancy Check (CRC) thereby stopping corrupt signals from being processed by the microcontroller.

The software

Whether in a highly sophisticate GUI or in a simple program running on a microcontroller, most robots would require some form of software. Two separate sets of software had to be created. The first was created to run on the PC. This would contain the GUI that communicates directly with the user. The other would run on the various microcontrollers on the modules. An extensive research on the programming language that would be most suitable was carried out. The Visual Basic 6.0 (Enterprise Edition) programming language for the Graphical User Interface software and C programming language for the microcontroller program software was used [1].

Camera

Since the robot is to be operated remotely, we decided to use a wireless video camera for visual feedback. The camera was mounted on top of the robot. Since the camera was to be cordless, we only considered the IP camera and the wireless CCTV.

The Swann Night Hawk Camera allows you to transmit pictures and sound with ease. It transmits radio waves at a frequency of 2.4GHz. It can be received within a radius of up to 100 meters in open line of sight. The receiver can be connected to a TV or PC (using a TV to PC adapter). It was chosen because it consumes little power and has night vision.

Sensors

Sensors provide feedback for some environmental conditions. These sensors include Electronic Thermometer, Rain Detector, and Smoke Detector.

DESIGN AND IMPLEMENTATION

This mobile robot is controlled by a computer wirelessly. This robot has a control unit/module which can be directly connected to a PC's parallel port. This robot itself is controlled by a microcontroller which drives the actuators (DC motors and the stepper motor). This microcontroller receives commands from the PC over RF (radio frequency).The control module uses an encoder to change instructions from parallel to serial transmission over a single communication channel using an RF transmitter IC. An RF receiver was used and a decoder was used to change serial data into parallel. The robot is mounted with sensors. It has an encoder and an RF transmitter for sending data acquired by the sensors. The control unit has an RF receiver and a decoder for receiving what is transmitted by the robot.For the motor drivers, we used a combination of NPN/PNP power and switching transistors ICs. The factors considered in choosing these were current (ampere) rating, voltage rating and switching speed. Suitable IC packages with multiple transistors were used to achieve a more compact control circuit.

Mechanical Design and Fabrication of the Robot

This aspect of the robot design entails the hardware part of the project. It includes: the robot frame, motors and the drive systems. We must mention here that due our limited knowledge in the field of mechanical engineering and in the operation of some machines in this field we consulted the assistance of experts.

Robot Base, Locomotive System, and Camera Base

Due to the weight of the materials on the robot (battery, motors chains, camera, circuit boards etc.), the base was constructed with a steel material with thickness of about 4 mm. Figure 3 below shows the dimension of the base of the robot, Robot's Heavy-Duty Drive wheel (4.3-inch Diameter), and Camera Mounting Base. The dimension for the base of the robot was chosen to after adequate calculations to accommodate the other mechanical component of the robot.

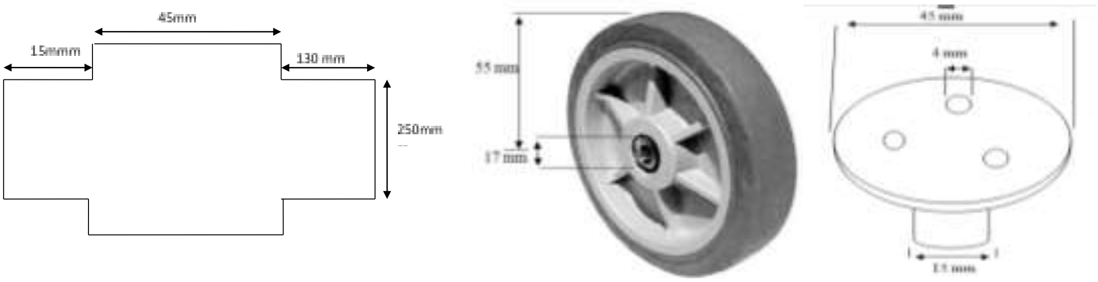

Figure 3: Dimension of the Base of the Robot; Robot's Heavy-Duty Drive wheel (4.3-inch Diameter); and Camera Mounting Base

The components used to achieve the locomotive part of the robot include: the tyres, the dc motors, chains, the pillow bocks, and sprockets. Figure 3 above shows the tyre used and its dimensions. The wireless CCTV camera was mounted on a base on the robot. The base was given little elevation to give the camera a wider coverage area. The base is made of a circular 4 mm thick steel sheet. The base dimension is shown in figure 3. The camera was attached to the base using screws of 4 mm diameter. The entire base was mounted on stepper motor directly beneath the roof of the robot so that the rotation of the stepper motors rotates the camera.

The differential drive system used in this project is the differential drive system which uses two motors, one for each wheel. The motors were connected in such a way that the chains run from the sprocket attached to the motor to the hind wheel and from the sprocket attached to the hind to the front wheel as shown in figure 4.

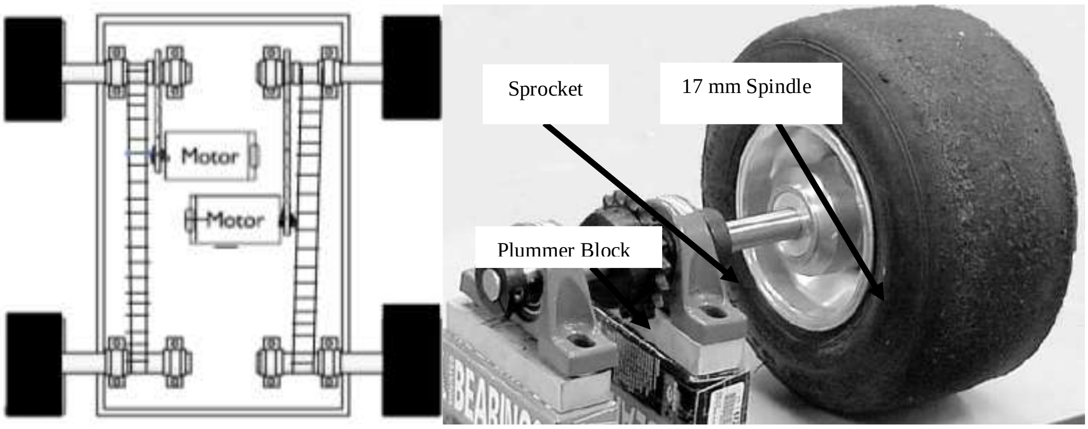

Figure 4: Schematics of Motor Arrangement, and Arrangement of the Wheels and Axle

Mounting and Supporting the Wheels and Axles

The mounting of the wheel to the axle and other locomotive parts of the system determines to a great extent the stability of the robot. Not only must the complete wheel assembly be securely attached to the axle, but the wheel should ideally be able to be easily removed if repairs and replacements are necessary during the operation of the robot. The configuration used in this project is an arrangement where an axle is supported by two pillow block bearings. A sprocket is located between the pillow blocks, and the wheel is located to one side of the pillow blocks. The hind wheels, however, have two sprockets to transmit the torque to the forward wheel.

Electronic Hardware

The electronic hardware of our circuit consists of the transmitter unit, the receiver unit, the motor controller, the sensors, and the power supply [1-3].

Software Design [4-7].

The Robotic system uses three AT87S51 microcontrollers; each of the microcontrollers was programmed using C programming language. The receiver microcontroller is programmed such that for each decoded bit stream received, the microcontroller performs a desired action by sending a high to certain I/O ports which are directly connected to the actuators of the robot

The GUI is the interface between the end user and the program. In the GUI, no codes are seen, what is made available are interactive control which the end user manipulates in order to cause and event. The GUI was done using Microsoft visual basic 6.0 (enterprise Edition).The GUI comprises of two interfaces these are theSplash Screen Interface and Control Interface.

The splash screen interface is the first interface that pops up as soon as the program is loaded or activated. It creates the illusion of time delay while the program loads up its data and controls. It is shown below in figure 5.

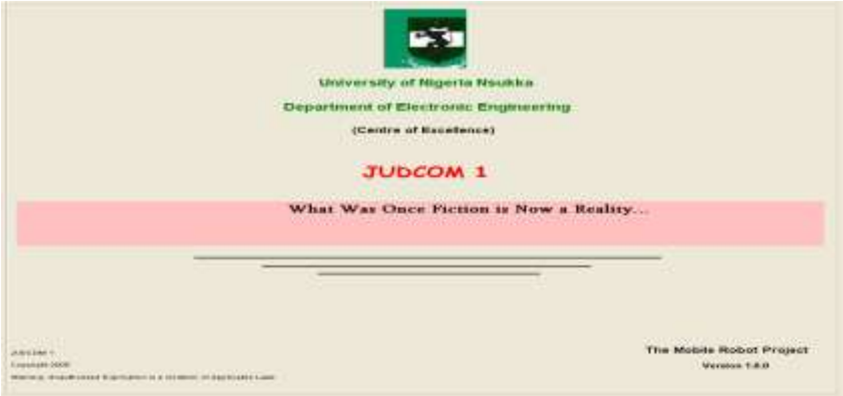

Figure 5: Splash Screen

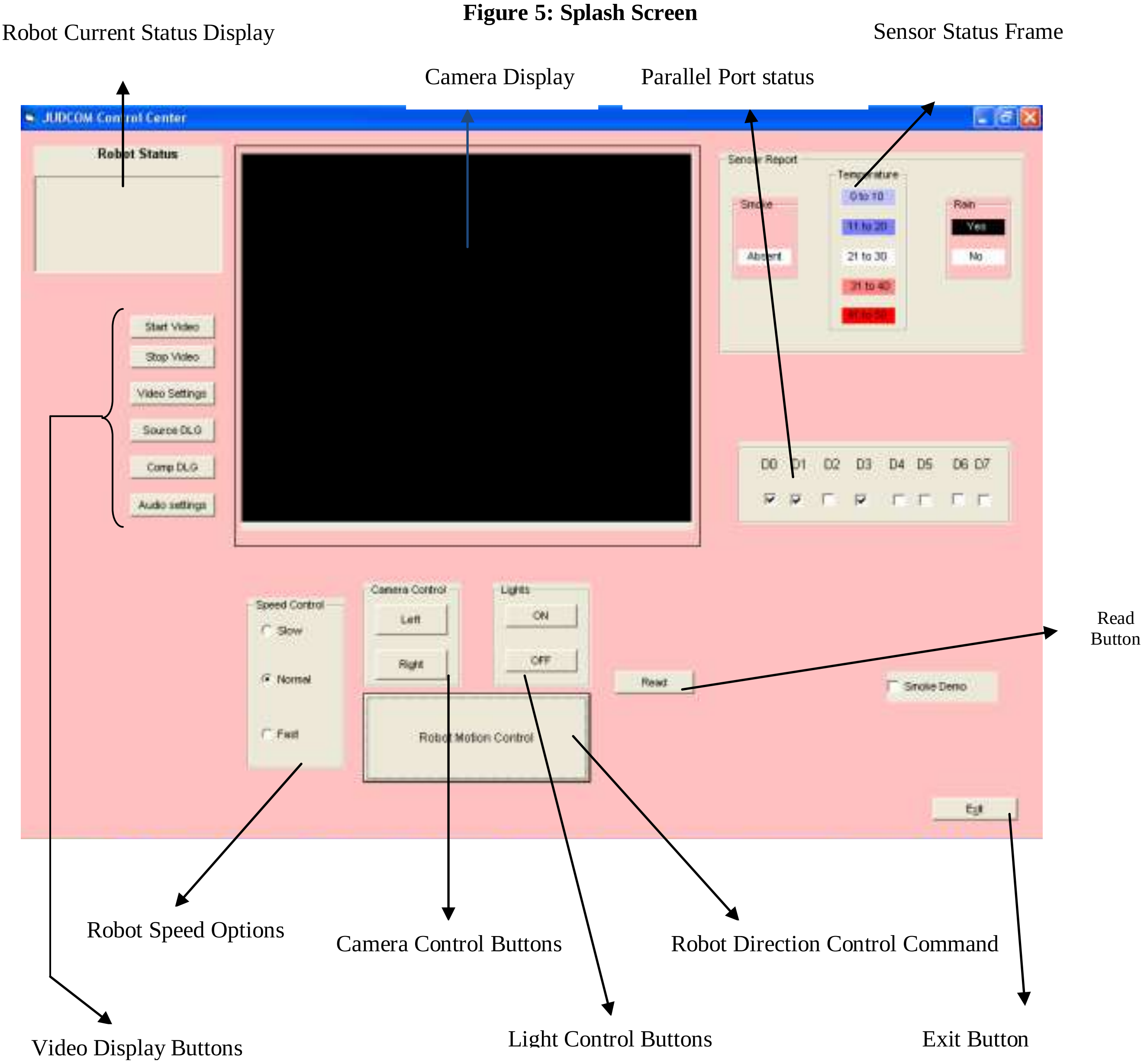

Figure 6: Main Graphical User Interface (Control Interface)

The Control Interface could be viewed as the main GUI. All control actions targeted at the robot emanate from this interface. Figure 6 below shows a pictorial description of the control interface.

Controls, Commands and Display Objects Used

Robot Motion Control Button:

Once the Robot motion button is clicked, it activates key board inputs. The operation is such that when one of the coded keys is pressed on the keyboard, a string of pre encoded 4 bits are sent out via the parallel port. The encoded buttons for the Robots motion are listed in the table 1:

Table 1: Button Assignments for Robot Motion

Keyboard Input Button	Robot Motion Response
W	Forward Motion
S	Reverse Motion
A	Left Turn
D	Right Turn
Q	Slow Left Turn
E	Slow Right Turn

A careful view of a standard keyboard shows the relative closeness of these buttons. These buttons have been chosen to allow for very easy control and manipulation of robots direction motion.

Flow Charts of Operation of the GUI

The Flow charts describing the Sensor Report Mechanism is shown below.

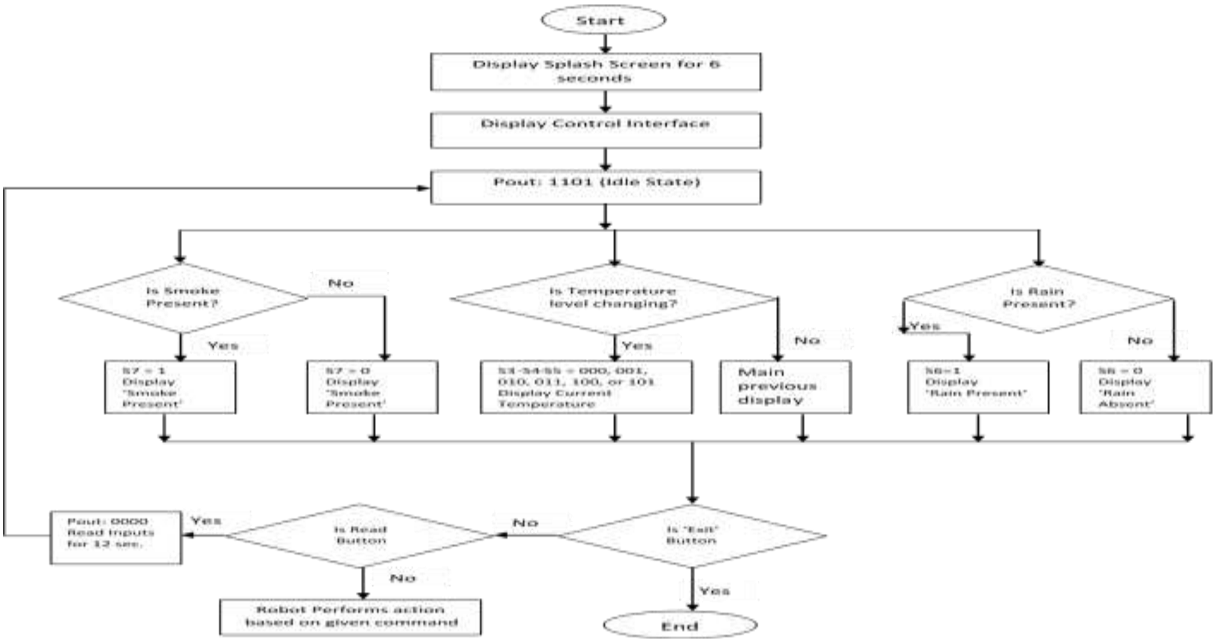

Figure 7: Flow chart for Sensor Report Mechanism:

System Integration and Testing

The circuit design of the robot was split into module to reduce the complexity of the system and to ease troubleshooting. The different units of the project include: robot fabrication, locomotive system design and assembly, control circuit design and implementation, power supply design, design and implementation of wireless communication module and software development for both the GUI and microcontrollers. These tasks were allocated among the members of the group and who constantly met to establish and update guidelines that will ensure the compatibility of the various modules during system integration.

Most of the circuits were first implemented on bread boards. A back up circuit was designed using Vero board. This became necessary due to the difficulty we encountered attempting to build the printed circuit board. The individual circuit boards were tested for basic errors and also for functionality where applicable. We ensured that the desired voltage levels were supplied to the ICs. During testing, some components were damaged and replaced. The wireless communication module for the camera and the robot transceiver circuit was implemented and tested with a sample circuit and we were able to achieve a range of about 60 meters. Having tested the various modules, the system integration was done in stages. All the individual circuits were integrated and tested. We had difficulty achieving communication with the receiver and the transmitter. Some power supply issues were encountered, such as supply voltage dropping significantly when the robot moves for a short while.

The bits from the parallel port and into the parallel port where tested by the parallel port status on the GUI. We then checked the motion of the robot when the right bits where sent to the micro controller of the motor controller. The entire system was then tested.

CONCLUSION

This project is a redesign of an existing work with added features to meet the current trend in robotics and in computer networking. A completely mobile robot with more sensors was achieved. A previous work on robotic arm was analysed with a view of improving it and meeting the limitations encountered. Some of which are:

- Insufficient motor torque and torque amplification with gears, to support the robot and any added weight
- Heavy weight of robot arm due to material used (steel)
- Failure to achieve the required six degrees of freedom for the robot arm
- Lack of flexibility in the entire system since a computer (PC) was directly attached to the robot control circuitry, and a few others.
- Through Research, these Limitations were met as explained below:
- Through our choice of dc motor, we were able to provide sufficient torque to move the robot and any other weight added to it. DC motors have more torque than the stepper motors.
- Flexibility of the entire system was achieved since the computer (PC) was not directly attached to the robot control circuitry. The communication with the robot is wireless using radio frequency (RF).
- Mobility of the entire robot was achieved
- The use of a special type of aluminum sheet as against heavier steel reduced the weight of the robot to an extent although with a little increase in cost.

Other Achievements Include:

- The used encoders and decoder at transmission and reception to achieve:Noise reduction and Security – since we used wireless means to communication it will be possible for a receiver on the same channel to receive what we are transmitting, it becomes necessary that we secure the data by coding it at the transmitting end and decoding it at the receiving end.
- The use of printed circuit boards (PCB) to do the circuits. This reduces the errors due to faulty connections and wiring usually found on other boards.

Limitations

- The Mechanical Limitations of this project include Heavy Weight of Robot being about 25.5Kg due to limitation in the availability of appropriate material; and Poor Mechanical Clearance to aid overcoming small obstacles like stones and pebbles while in motion.
- Electrical Limitation includes Short Battery Life as SLA batteries have a relatively short life; and Software limitation such as large memory requirement for microcontroller c programming, speed reduction in c programmed microcontroller, and lack of object orientation in VB6.

Recommendations

From the experience gathered in the implementation of this project as well as the limitations encountered, we recommend that for the future implementation of this project, the following improvements can be made:

- Belt drive can be used instead of the chain drive. This will greatly reduce the weight of the robot
- A self-supporting dynamo can be achieved by using the rotation of the drives (belt or chain) to charge the battery hence ensuring steady self-generated power supply for the robot whenever it is in motion.
- The project can be a joint project with some student from the mechanical engineering department. This will help improve the quality of design of the mechanical part of the project.
- Addition of internet accessibility option to the GUI so that if the robot is applied as a security system, it could be viewed from anywhere in the world.
- Use of Tyres with larger diameter. This would help solve the limitation of poor clearance. To increase the range of the transmitted signal the Transmitter and receiver with higher range can be used.
- The camera arm can be replaced with full robotic arm with grips. This can be used in factories to lift objects.
- The robot can be given added intelligence so that it can sense obstacles and respond appropriately.

We will not deny the fact that this project just like most projects in robotics, is cost-intensive, time-consuming, and brain-tasking. But the end, indeed justified the means. Not only were we able to meet the limitations encountered by the last group, we were able to meet our set objectives. We are proud to have achieved the design of a completely mobile robot with wireless control – our own little way of contributing to the growth of robotics in our beloved country Nigeria.We also believe that the limitations we encountered in the course of this project can be overcome. And with the recommendations enumerated above further improvement on this work is possible.Truly, our mobile robot (JUDCOM1) which was once fiction is now a reality, thanks to the Art of Electronics.

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