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Microcomputer Controlled Color Identification Robot Arm

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Abstract
In this twenty first century, there is an increasing need to create artificial arms for different inhuman situations where human interaction is difficult or impossible. The application of robots in solving human needs has enhanced man's performances, especially in the issue of color blindness in human and inconsistency with color identification. The research work is to design and construct a robot arm that is controlled by a Computer system that can Identify Color. This research work can be achieved by develop a robot arm with four degree of freedom that is downward and upward movement, clockwise and anticlockwise movement. In this system, Modularization Methodology was used which involved the breaking down of large systems into smaller parts (module). Each module was constructed independently to optimize the full function of the entire system. The three primary colors identified were Red, Green and Blue. The identification of a particular color was done by light intensity to frequency converter method. The Arduino Uno provided an interface with the control circuit and computer system via USB cable. The Relay controlled the movement of the robot by sending signal to the DC motors. The TSC3200 programmable color sensor was used to detect and measure the visible range of the colored materials from the work space. The research project successfully carried out the task of identifying the color of object at the preprogrammed work place. This robot can be used as Color sorter and Agricultural machine.
Index Items: *Robot Arm, TSC3200 Colour Sensor, Arduino Uno and DC Motor*

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I. Introduction

Robots are currently being incorporated into working tasks to replace human beings especially to perform the recurring tasks. It might be difficult or dangerous for man to do some specific works like picking up explosive chemicals, defusing bombs or in worst case scenario to pick and place the bomb somewhere for safety purpose, for repeated pick and place actions in industries. Therefore, substituting works done by human with robots significantly becomes imperative.

There are basically two kinds of robots: Service and Industrial robots. Service robot is a robot that operates semi or fully autonomously to perform services useful to the well-being of humans and equipment. These robots are currently used in many fields of applications including Offices, Military tasks, Medical operations, Dangerous environments, and Agriculture, including manufacturing operations.

Industrial robot, on the other hand, is officially defined by International Standard Organization (ISO) as an automatically controlled and multipurpose manipulator programmable in three or more axis (Ashraf,et al,. 2011). Industrial robots are designed to move materials, parts, tools, or specialized devices through variable programmed motions to perform some variety of tasks. Industrial robot system includes not only industrial robots but also other devices and/or sensors required for robots to perform their task as well as sequencing or monitoring communication interfaces.

A robot arm is usually programmed, with similar functions to a human arm. The links of such a manipulator are connected by joints allowing either rotational motion (such as in an articulated robot) or translational (linear) displacement. The links of the manipulator can be considered to form a kinematic chain. The business end of the kinematic chain of the manipulator is called the End Effectors and it is analogous to the human hand. The end effectors can be designed to perform any desired task such as welding, gripping, spinning etc., depending on the application. The robot arms can be autonomous or controlled manually and can be used to perform a variety of tasks with great accuracy. The robot arm can be fixed or mobile (i.e. wheeled) and can be designed for industrial or home applications (Mohd, et al, 2012) and (Wan, et al, 2012).

This work is titled Microcomputer Controlled colour identification Robot Arm which identifies different color of an object by using a TCS3200 programmable color sensor. It is a robot arm that is developed to have four degree of freedom movement; upward, downward, clockwise and anticlockwise. The TCS3200 programmable color sensor attached to the robot arm at the end effector does the color identification.

Robots are indispensable in many factoring industries. The reason is that the cost per hour to operate a robot is a fraction of the cost per hour to operate a human labor needed to perform the same function. More than this, once programmed, robots repeatedly perform function with a high accuracy that surpasses that of the most experienced human operator. Human operators are, however, for more versatile. Humans can switch job tasks easily. Robots are built and programmed to be job specific. You wouldn't be able to program a welding robot to start counting parts in a bin. The circuit component includes relays and Arduino uno. Relay is a switch that opens and closes a circuit electromagnetically or electrically. Arduino Uno is an open-source platform used for building electronics projects. Arduino is made up of both a physical programmable circuit board (microcontroller as it is been referenced to) and a piece of software, or Integrated Development Environment (IDE) that runs on your computer, used to write and upload computer code to the physical board. The arm is powered by two DC motor. These motors are connected to the common connectors of the relay module and the digital pins of the relay are connected to the arduino uno digital pin. The Arduino board is interfaced with the computer system via Universal Serial Bus (USB) communication port. Where the movement of the robot arm is been controlled by using the computer I/O devices to input the direction of motion. Figure 1 below illustrates the Free Body Diagram of mechanical design of the robot arm. They functions of the microcomputer are to process the inputs received from the computer I/O and perform the action programmed. The relay is powered by 12V from the power pack of a computer system and Arduino 5V.

II. Robot

A robot is a mechanical or virtual artificial agent, usually an electro-mechanical machine that is guided by a computer program or electronic circuitry. Robots can be autonomous or semi-autonomous. The design, construction, operation, and application of robots (Oxford Dictionaries) as well as computer systems for their control, sensory feedback, and information processing are branch of technology called robotics. In a dangerous environments or manufacturing processes, these technologies deal with automated machines that resemble humans in appearance, behavior takes the place of humans in most of the applications. Many of the robots are nature inspired contributing to the field of bio-inspired robotic

Robot arm

It is a type of mechanical arm, usually programmable, with similar functions to a human arm; the arm may be the sum total of the mechanism or may be part of a more complex robot. The links of such a manipulator are connected by joints allowing either rotational motion (such as in an articulated robot) or translational (linear) displacement. The links of the manipulator can be considered to form a kinematic chain. The terminus of the kinematic chain of the manipulator is called the end effector and it is analogous to the human hand (Deepuk et al., 2014.). The end effector, or robotic hand, can be designed to perform any desired task such as welding, gripping, spinning etc., depending on the application. For example robot arms in automotive assembly lines perform a variety of tasks such as welding and parts rotation and placement during assembly.

The Three Laws:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given to it by human beings, except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

A robot may not harm humanity, or, by inaction, allow humanity to come to harm. This led to introduction of zeroth law.

Principles of Robotics

In 2011, the Engineering and Physical Sciences Research Council (EPRSC) and the Arts and Humanities Research Council (AHRC) of Great Britain jointly published a set of five ethical "principles for designers, builders and users of robots" in the real world, along with seven "high-level messages" intended to be conveyed, based on a September 2010 research workshop. (Winfield, 2011) and (Stewart, 2011).

1. Robots should not be designed solely or primarily to kill or harm humans.
2. Humans, not robots, are responsible agents. Robots are tools designed to achieve human goals.
3. Robots should be designed in ways that assure their safety and security.
4. Robots are artifacts; they should not be designed to exploit vulnerable users by evoking an emotional response or dependency. It should always be possible to tell a robot from a human.
5. It should always be possible to find out who is legally responsible for a robot.

The messages intended to be conveyed:
1. We believe robots have the potential to provide immense positive impact to society. We want to encourage responsible robot research.
2. Bad practice hurts us all.
3. Addressing obvious public concerns will help us all make progress.
4. It is important to demonstrate that we, as roboticists, are committed to the best possible standards of practice.
5. To understand the context and consequences of our research, we should work with experts from other disciplines, including: social sciences, law, philosophy and the arts.
6. We should consider the ethics of transparency: are there limits to what should be openly available?
7. When we see erroneous accounts in the press, we commit to take the time to contact the reporting journalists.\

III. Analysis Of The Existing System

The project named Magnetic Material Separating Robot Arm was designed by a student of Computer Science Department. The scope of the project is to separate metallic material from non metallic material. The separating transducer is solenoid which is attached to the end effector. The circuit component includes relays, ICs and opto-couplers (Ituma et al., 2015). The arm is powered by two DC motor. In this particular project, PIC microcontroller is programmed into the instructions to control the servo motor. The analysis carried out in the course of the design of this system, 'Magnetic Material Separating Robot Arm, revealed that the system on ground used for material separation is fully automated and cannot separate this materials with their various colors thus, the process of material separation is very tedious (Ituma et al 2014). The current system is one that is made up of the solenoid. This arm has the ability of making the four (4) basic movements (upward, downward, clockwise and anticlockwise movements). The magnetic separating arm that is currently in place makes use of a solenoid in the separation. This solenoid at the end effector can separate magnetic and non magnetic material but cannot identify different colors of materials both magnetic and non magnetic.

The block diagram of the micro computer based magnetic material separating robot shows the flow of signal among the various component of the system. From the fig.20 you can see how the signal flows from a power supply into the control circuit and from the computer into the control circuit. Then from the control circuit, the signal is sent to the robot motors and solenoid.

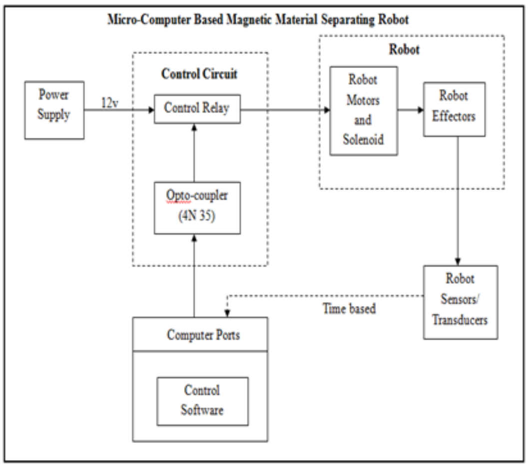

Fig 1: Block Diagram of Existing System (www.ijser.org Ituma et al., 2015)

There material separating engineer that work with the system, to identify different colors find it very difficult to separate the objects. They also used other methods of separating materials which include hand-picking the materials and thus make a separation of the materials difficult. This mode of material separation is as well very tedious and prone to error as man can be easily fatigued, thereby leading to unnecessary errors in the course of the separation. Separation of this material from magnetic and non magnetic material was achieved successively but the problem faced with was how to separate all those material to different colors so that production will be much faster and timely.

Limitations of Existing System

As earlier stated in the above subsection, the process of magnetic material separation is fully automated. Materials that are automatically dropped (i.e the magnetic and non-magnetic) but without the help of a material identify engineer it seem very difficult in the identifying those materials into their different colors. As the system operator will still have to attend to the identifying process. This is a very serious issue as the system is supposed to ease man's pains in the course of material identification, not to add more to the stress (Ituma, et al., 2015). The basic limitation of the existing system is its inability to separating those magnetic material and non magnetic automatically with their different colors.

High Level Model Diagram

The high level model diagram of the Microcomputer Controlled Color Identification Robot Arm shows how signal flow among the various component of the system. From the figure 21 you can see how the signal flows from a 12volt power supply pack of a computer into the relay control of a control circuit. The relay controls the directional movement of the robot arm through the robot motor. The 5volt power supplied from the computer system powers the arduino uno board of the control circuit. The power from the arduino uno activates the digital pins of the relay and also the robot sensor for color identification. The robot sensor sends the feedback to the control software via serial monitor. The serial monitor on the control software is where the output operation of the robot arm is displayed. The programmer input signal through the computer input and output devices.
Then from the control circuit, the signal is sent to the robot motors and TSC3200 programmable color sensor.

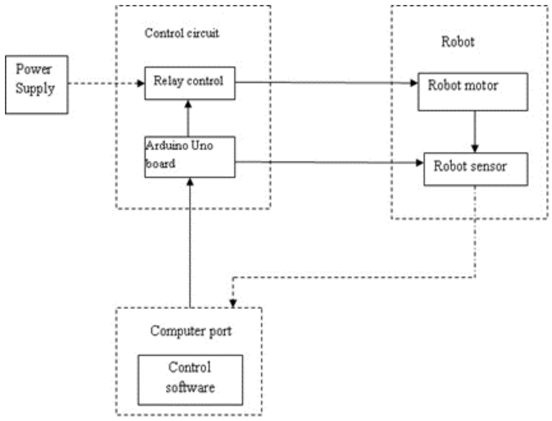

Fig 2: High Level Model Diagram of Envisaged System

Justification of the Proposed System.

At this section of the system analysis, we looked into the performance evaluation of the proposed system so as to deduce a perfect system justification. As stated above, the existing system has the basic limitation of not separating of different color of materials automatically. Attending to this separation process led to the introduction of TCS3200 Color Sensor. TCS3200 Color Sensor is a complete color detector, including a TAOS TCS3200 RGB sensor chip and 4 white LEDs. The TCS3200 can detect and measure a nearly limitless range of visible colors. Applications include test strip reading, sorting by color, ambient light sensing and calibration, and color matching, to name just a few. The TCS3200 has an array of photodetectors, each with either a red, green, or blue filter, or no filter (clear). The table 1 below shows the pin description of the TCS color sensor. The filters of each color are distributed evenly throughout the array to eliminate location bias among the colors. Internal to the device is an oscillator which produces a square-wave output whose frequency is proportional to the intensity of the chosen color.

Structure of the Robot

The system is made up of three essential parts (robot arm, interfacing circuit and control software). These parts include the hardware which is the robot arm itself that is responsible for the identification and movement. Then we have the control circuit which acts as a medium between the robot arm and the computer. The next is the control software which provides the interface that the user uses to interact with the whole system. This user interface has the function of controlling the movement of the robot arm.

The Robot Arm

This is made up several metallic components which are welded together. The robot arm has an effector, shoulder and a base which are all made of metal. On these parts component like the DC Motor, Gear, Bridges and TSC3200 Programmable Color Sensor are attached to the robot. The components that make up the robot arm includes

- End Effector
- Gear
- Dc motor
- Bridge or Switch

- TSC3200 Programmable Color Sensor
- Wire

End Effector

This is any part of the robot that affects the environment. Effectors may be legs, wheels, arms, fingers, wings or fins. Controllers use the effector to produce the desired effects on the environments. In the case of this robot arm the effector are two i.e. the arm and the shoulder effector. The arm effector is attached to the shoulder effector which is mounted on a metallic base. The arm effector of the microcomputer controlled color identification robot arm under the control of two DC motors makes a total of four movements i.e. upwards, downwards, clockwise and anticlockwise movement. It makes the movement depending on the signal that is sent to DC motors.

Gear

A gear is toothed machine part, such as wheel or cylinder that meshes with another toothed part to transmit motion. This gear is attached to DC motor that controls the effector. The speed of the motor is counted in terms of rotations of the shaft per minute. Using the combination gears in a motor, its speed can be reduced to any desirable figure.

DC Motor

A DC motor is a fairly simple electric motor that uses electricity and a magnetic field to produce torque which causes it to turn. It uses magnetic properties of attraction and repulsion to convert electricity into motion. They are two DC motors on this robot one is at the base of the robot and it in control of the movement of the effector in clockwise and anticlockwise direction i.e. base movement. The second motor attached on the shoulder of the effector controls upwards and downwards of the effector.

Bridges (Switches)

These are made of plastic (pegs) and are positioned at the edges of the robot to act as a bridge to the shoulder. When the shoulder moves to the desired length the peg stops it from making any further movement beyond the limit. The pegs are attached to the robot with a binding wire which is welded to the robot to make it firm and tight. These bridges are controlled by the switch on the circuit. And once the robot edge touches the peg the action is suspended.

TCS3200 Programmable Color Sensor

TCS3200 Color Sensor is a complete color detector, including a TAOS TCS3200 RGB sensor chip and 4 white LEDs. The TCS3200 can detect and measure a nearly limitless range of visible colors. Applications include test strip reading, sorting by color, ambient light sensing and calibration, and color matching, etc. The TCS3200 has an array of photodetectors, each with either a red, green, or blue filter, or no filter (clear). The filters of each color are distributed evenly throughout the array to eliminate location bias among the colors. Internal to the device is an oscillator which produces a square-wave output whose frequency is proportional to the intensity of the chosen color

Interfacing Circuit Design

The design of the interfacing circuit is done in modules as earlier stated in the previous chapter. This adopted methodology makes it possible for the whole circuit to be divided into sub-modules.

Components of the Control Circuit

The control circuit is built on a Vero-board. This board serves as an anchor to all other components that are attached to it. The various components which made up the control circuit include;

- Arduino Uno
- Relay
- Wires
- Switch
- Power supply source

Arduino Uno

It is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board. The Arduino platform has become quite popular with people just starting out with electronics, and for good reason. Unlike most previous programmable circuit boards, the Arduino does not need a separate piece of hardware (called a programmer) in order to load new code onto the board – you can simply use a USB cable. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program. Finally, Arduino provides a standard form factor that breaks out the functions of the micro-controller into a more accessible package.

There are many varieties of Arduino boards that can be used for different purposes. Some boards look a bit different from the one below, but most Arduinos have the majority of these components in common:

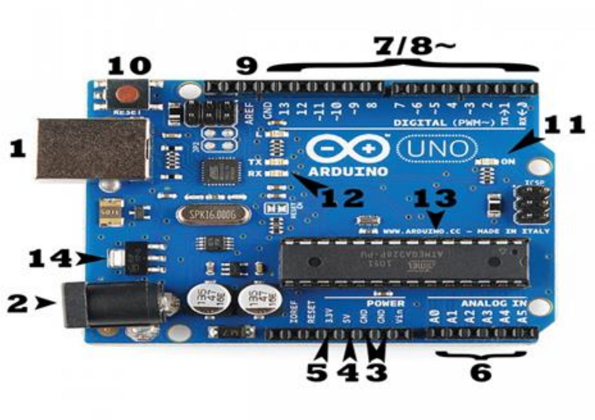

Fig 4 Arduino Uno Board (www. Sparkfun electronics)

Power (USB / Barrel Jack)

Every Arduino board needs a way to be connected to a power source. The Arduino UNO can be powered from a USB cable coming from your computer or a wall power supply (like this) that is terminated in a barrel jack. In the picture above the USB connection is labeled (1) and the barrel jack is labeled (2). The USB connection is also how you will load code onto your Arduino board. More on how to program with Arduino can be found in our Installing and Programming Arduino tutorial. Do not use a power supply greater than 20 Volts as you will overpower (and thereby destroy) you're Arduino. The recommended voltage for most Arduino models is between 6 and 12 Volts.

Pins (5V, 3.3V, GND, Analog, Digital, PWM, AREF)

The pins on your Arduino are the places where you connect wires to construct a circuit (probably in conjuction with a breadboard and some wire. They usually have black plastic 'headers' that allow you to just plug a wire right into the board. The Arduino has several different kinds of pins, each of which is labeled on the board and used for different functions.

- GND (3): Short for 'Ground'. There are several GND pins on the Arduino, any of which can be used to ground your circuit.
- 5V (4) & 3.3V (5): As you might guess, the 5V pin supplies 5 volts of power, and the 3.3V pin supplies 3.3 volts of power. Most of the simple components used with the Arduino run happily off of 5 or 3.3 volts.
- Analog (6): The area of pins under the 'Analog In' label (A0 through A5 on the UNO) are Analog In pins. These pins can read the signal from an analog sensor (like a temperature sensor) and convert it into a digital value that we can read.
- Digital (7): Across from the analog pins are the digital pins (0 through 13 on the UNO). These pins can be used for both digital input (like telling if a button is pushed) and digital output (like powering an LED).
- PWM (8): You may have noticed the tilde (~) next to some of the digital pins (3, 5, 6, 9, 10, and 11 on the UNO). These pins act as normal digital pins, but can also be used for something called Pulse-Width Modulation (PWM). We have a tutorial on PWM, but for now, think of these pins as being able to simulate analog output (like fading an LED in and out).
- AREF (9): Stands for Analog Reference. Most of the time you can leave this pin alone. It is sometimes used to set an external reference voltage (between 0 and 5 Volts) as the upper limit for the analog input pins.

Reset Button

The Arduino has a reset button (10). Pushing it will temporarily connect the reset pin to ground and restart any code that is loaded on the Arduino. This can be very useful if your code doesn't repeat, but you want to test it multiple times. Unlike the original Nintendo however, blowing on the Arduino doesn't usually fix any problems.

Power LED Indicator

Just beneath and to the right of the word "UNO" on your circuit board, there's a tiny LED next to the word 'ON' (11). This LED should light up whenever you plug your Arduino into a power source. If this light doesn't turn on, there's a good chance something is wrong. Time to re-check your circuit!

TX RX LEDs

TX is short for transmit, RX is short for receive. These markings appear quite a bit in electronics to indicate the pins responsible for serial communication. In our case, there are two places on the Arduino UNO where TX and RX appear – once by digital pins 0 and 1, and a second time next to the TX and RX indicator LEDs (12). These LEDs will give us some nice visual indications whenever our Arduino is receiving or transmitting data (like when we're loading a new program onto the board).

Main IC

The black thing with all the metal legs is an IC, or Integrated Circuit (13). Think of it as the brains of our Arduino. The main IC on the Arduino is slightly different from board type to board type, but is usually from the ATmega line of IC's from the ATMEL company. This can be important, as you may need to know the IC type (along with your board type) before loading up a new program from the Arduino software. This information can usually be found in writing on the top side of the IC. If you want to know more about the difference between various IC's, reading the datasheets is often a good idea.

Voltage Regulator

The voltage regulator (14) is not actually something you can (or should) interact with on the Arduino. But it is potentially useful to know that it is there and what it's for. The voltage regulator does exactly what it says – it controls the amount of voltage that is let into the Arduino board. Think of it as a kind of gatekeeper; it will turn away an extra voltage that might harm the circuit. Of course, it has its limits, so don't hook up your Arduino to anything greater than 20 volts.

Relay

Relays are switches that open and close circuit electromagnetically or electrically. Relays control one electrical circuit by opening and closing contacts in another circuit. There are four relays on this circuit used by the two DC motors. As shown in the relay diagrams below, when a relay contact is normally open there is an open contact when the relay is energized. When the relay is normally closed contact, there is a closed contact when the relay is energized. In either case, applying electrical current to contacts will change their state. The relay serves the function of turning on the motor to move in a clockwise or anticlockwise direction. The diagram below illustrates the connection of relay digital pin to the digital pin of an Arduion board. In this project the digital pins from relay; IN1, IN2, IN3, IN4 are connected to the Arduino digital pin in this order pin 4,3,2,0 respectively. The 5V (VCC) power supply from the Arduino supply power to digital pin on the relay and the ground (GND) is also grounded at the digital pin ground on the Arduino Uno. The power pack of the computer system supply 12v to the relay module through the common open terminal and the ground from the common close is connected to the power pack ground.

IV. Methodology

Modularization Design Approach

Modularization Methodology is a design approach that subdivides a large system into smaller parts called modules or skids that can be independently created and then used in different systems. A modular system can be characterized by functional partitioning into discrete scalable, reusable modules, rigorous use of well-defined modular interfaces, and making use of industry standards for interfaces (Ituma, et al., 2015)

Benefit of Modularization

(1) Reduction in cost (due to less customization, and shorter learning time).
(2) Flexibility in design.
(3) Expansion (adding new solution by merely plugging in a new module).

Examples of modular systems are cars, computers, process systems, solar panels and wind turbines, elevators and modular buildings. Earlier examples include looms, railroad signaling systems, telephone exchanges, pipe organs and electric power distribution systems. Computers use modularity to overcome changing customer demands and to make the manufacturing process more adaptive to change. Modular design is an attempt to combine the advantages of standardization (high volume normally equals low manufacturing costs) with those of customization (Ituma, et al., 2015). A downside to modularity (and this depends on the extent of modularity) is that low quality modular systems are not optimized for performance. This is usually due to the cost of putting up interfaces between modules.

Choice of Methodology

As a result of the basic advantage of the Modularization Methodology which is making a large system easy to handle by breaking it down into smaller units, the design of the Microcomputer Controlled Color Identification Robot Arm adopts the Modularization Methodology despites its few weaknesses which will not interfere in the course of the system design (Ituma, et al., 2015). The control circuit is to be divided into modules which would be designed separately. They modules after each construction and testing will be integrated together to form a Microcomputer Controlled Color Identification Robot Arm. Each of the modules comprises of robot arm, relays, Arduino Uno, DC Motor, Power source unit and Color sensor. The robot arm which is made up of color sensor fixed at 120 degrees at the end effector of the arm. A DC Motor that allow an upward and down ward movement. The switch at the arm breaks the movement to avoid moving beyond the expected limit. The robot arm is fixed to the base, the base as a geared motor which is capable of rotating in 360 degrees around a vertical axis. But due to other design issues with physical obstructions it has been limited to180 degrees with the help of the switch at the base. The circuit component comprise of arduino that is made of hardware and software. The color sensor and robot arm control software program is embedded in Arduion uno hardware. The relay drives the movement of the robot arm.

V. System Design And Implementation

System Design

Systems design is the process of defining the architecture, logical, physical, components, modules, interfaces, and data for a system to satisfy specified requirements. Systems design could be seen as the application of systems theory to product development. There is some overlap with the disciplines of systems analysis, systems architecture and systems engineering. (Bentley et al. 2004). System design gets commenced at the point where analysis stops. The information gathered in system analysis is used to accomplish the logical design of the Micro Computer Controlled color identification Robot arm.

Essentially, every hardware project has two basic components which are: hardware interface, interfacing circuit and control software. The hardware interface provides a platform which performs the physical operations, in this case, identification of color of an object. The interfacing circuit bridges the gap between the hardware interface and the control the software interactivity. The hardware interface is connected to the control circuit board (interfacing circuit) which is then connected to the computer system for control operations by the software. The control software in turn provides a medium which enables the user to have total control of the system. The system itself is made to function only with the help of the control circuit and software. The process of connecting all these functional parts to form a complete system is referred to as system automation.

Arduino and colour Sensor Connection

From the fig. 25 below shows the wiring or connection instruction of the color sensor to Arduino Uno. It show that pin S0, S1, S2,S3 of the color sensor is connected to the digital pin of Arduino Uno pin D3,D4,D5 and D6. The power pin Vcc is connected to 5v of Arduino and ground to GND. The output pin of the color sensor is wired to the D2 of the Arduino pin.

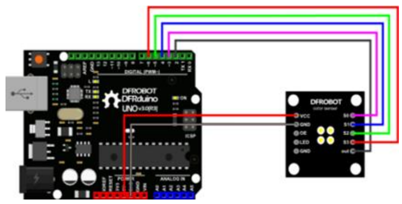

Fig. 5 Connection Diagram to the color sensor (source: robot wiki)

Table 1 Pin Description TCS 3200 Programmable Sensor

	Pin name	Input /output	Description
1	GND(4)		Power supply ground.
2	OE(3)	INPUT	all voltages are
3	OUT	OUTPUT	referenced to GND
4	S0,S1(1,2)	INPUT	Enable for fo (active
5	S2,S3 (7,8)	INPUT	low).
6	VDD (5)		Output frequency (fo).
			Output frequency
			scaling selection inputs.
			Photodiode type
			selection inputs
			Supply voltage

TCS3200 when choosing a color, it can allow only one particular color to get through and prevent other color. For example, when choose the red filter, only red incident light can get through, blue and green will be prevented. So we can get the red light intensity. Similarly, when choose other filters we can get blue or green light. TCS3200 has four photodiode types. Red, blue, green and clear, reducing the amplitude of the incident light uniformity greatly, so that to increase the accuracy and simplify the optical. When the light project to the TCS3200 we can choose the different type of photodiode by different combinations of S2 and S3. Looking at table below shows the color type

Table 2 Color Type

S2	S3	PHOTODIODE TYPE
L	L	RED
L	H	BLUE
H	L	Clear (no filter)
H	H	GREEN

In table 2 below, TCS3200 can output the frequency of different square wave (occupies empties compared 50%), different color and light intensity correspond with different frequency of square wave. There is a relationship between the output and light intensity. The range of the typical output frequency is 2HZ~500KHZ. We can get different scaling factor by different combinations of S0 and S1.

Table 3 Output Frequency Scaling

S0	S1	OUTPUT FREQUENCY SCALING (fo)
L	L	Power down
L	H	2%
H	L	20%
H	H	100%

System Specification

Bearing in mind that the proposed system is to be used for material identification, proper specification of the object used in the development of the project can go a long way in making sure that the goal is achieved. Specification is a means through which the user of the software and software designer communicate with each other understandably. We are going to go through some system specifications that form the basic specification document for the system

Main Menu Specification

The main menu specification of the proposed system looks at things that will be in place for proper interactivity of the system with the control software. This specifically looks at the main menu items such as menu buttons, command buttons, links and some other controls that see to the proper functionality of the system. Below is the sketch of the Main Menu

Fig 6a: Main Menu Specification

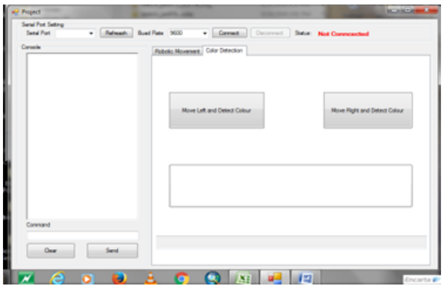

Fig 6b: Main Menu Specification

Table 4a: Property Setting for Main Menu Form

Control	Property	Setting
Form1	Name	frmMicrocomputerControlledColorIdentificationRobotArm
	Caption	Microcomputer Controlled Color Identification Robot Arm
Command1	Name	CmdMoveLeft
	Caption	Move Left
Command2	Name	cmdMoveRight
	Caption	Move Right
Command3	Name	cmdMoveUp
	Caption	move Up
Command4	Name	cmdMoveDown
	Caption	Move Down
Command5	Name	cmdMoveAllDirection
	Caption	Move All Direction

Table 4b: Property Setting for Main Menu Form

Control	Property	Setting
Form1	Name	frmMicrocomputerControlledColorIdentificationRobotArm
	Caption	Microcomputer controlled color identification robot arm
Command1	Name	CmdMoveLeftAndDetectColor
	Caption	Move Left and detect color
Command2	Name	cmdMoveRightAndDetectColor
	Caption	Move Right and detect color
Command3	Name	cmdDisplayColor
	Caption	Display color

Input Specification

The input specification deals with the various inputs a user of the control software will have to feed the system with to perform the desired operations. The user must take into cognizance, the right data to be fed to the system in order not to malfunction. Also, the consideration taken during the design stage of this control software tend to make sure that the system doesn't truncate or crash when wrong data if fed to the system; rather the system should generate some forms of exceptions and notify the user the kind of error generated so as to enable the user know the right thing to be done. The input forms used for exception handling include intelligent dialogue boxes, error flagging, etc. In the course of this project, intelligent dialogue boxes were used to inform the user of the errors encountered and as well inform him/her of the correct thing to be done.

Output Specification

The output specification deals with the output generated in the course of processing the user's input. Any intelligent system that does not generate a very good report after data processing is not to be considered for use. Therefore, there are output forms which show the result of the separation. This report takes into cognizance the number of times the arm made movements in the course of the identification. The output forms as well informs the user of his/her progress, where he/she has made mistakes and things that need to be done to correct the errors induced by the human operator.

Hardware and Software Specification

The Micro Computer Controlled Color Identification Robot Arm is developed using some certain specification of hardware and software requirement for the system. Table 5 is a summary of the specification that is to be met for system.

Table 5: Hardware and Software Specification

Hardware	**Specification**
Component	Specification
Processor Speed	750GHz and above
RAM Size	520MB and Above
Hard Disk Size	10GB and above
Video Card	Any video card that can give best resolution
Software Specification	
Operating System (OS)	Windows 98 and above

Layout Diagram of the Interfacing Circuit

The layout diagram of any circuit is designed to show how the interface of such circuit is being mapped out, the components arranged and how the connections are made on the circuit board (Vero board or bread board)

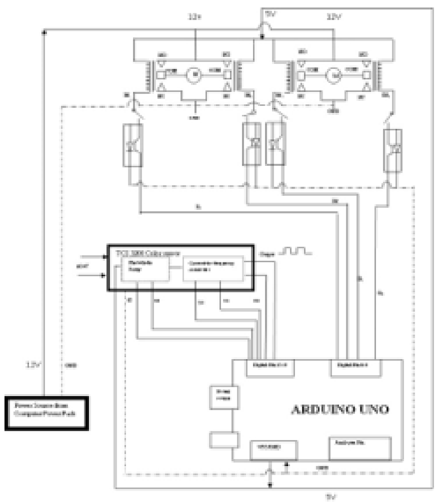

Fig 7: Wiring Diagram of Interfacing Circuit

In the above diagram, the Arduino Uno board is made up of some pins like digital pin 0 to 13, power pin and analogue pin. Digital pins with tide like pin ~3, ~5, ~6, ~9, ~10, ~11, are called the Pulse-width modulation (PWM). It is an easy method to vary the power using a digital signal, when an analog signal isn't available. Instead of controlling the current or voltage of a signal, a pulse-width-modulated signal works by repeatedly pulsing the digital signal high and low at a fast rate. The control signal is a pulse-width-modulated input signal whose high pulse width determines the servo's angular position when the relays are connected to these digital pins.

They are four relays placed on a straight line. The Digital pins on the relay board are labeled Vcc, GND, IN1, IN2, IN3, and IN4. The IN1 to IN4 are connected to any of the digital pin on the Arduino Uno board but on this project pin 0, 2, 3, 4 was used. After the relays are mounted successfully, they are tested individually to check if the connection between each leg was soldered properly. They Vcc and GND from the digital pins of the relay are connected directly to the power pin of the Arduino. The two servo motor or DC motor is connected to COMMON connectors of the relay for the movement of the robot arm i.e up and down, clockwise and anti clockwise if the logic status is 1 it is connect to common open if logical status is 0 it connect to common close. If the motor has a contact connected to the negative pole and one to the positive pole then it moves, if it has both contacts connected to the same pole is stopped.

The power supply, red and black wires is used to run through the relays. This wire is to supply the 12V to the relays from the power pack of a computer system. A black and brown wire same size as the first is connected to one of all the relays and is connected to the DC motors. The brown and white-brown wires are to serve as the ground of the motor. Another black colored wire is connected to the second relay. Similarly another wire brown in color is connected to the third relay and the same connection is done on the fourth relay. This is the connected to the second motor of the robot. These motors are responsible for the movement of the robots.

The eight (8) wires of TSC3200 programmable color sensor are connected to the digital pin, (PWM) and power pins of Arduino Uno. These digital pin are labeled D0-D13 with GND and AREF. The power pin has 3.3V, 5V, two GND, Vin, RESET and IOREF Pins and the Uno board is connected to the computer via (USB / Barrel Jack). From the Arduino programming environment the pins were connected to the TSC3200 color sensor in the manner illustrated: S0 – PIN 8, S1- pin 9, S2- pin 12, S3- pin 11, LED - pin 13, OUT- pin10, VCC – 5V and GND – GND pins respectively.

System Flowchart

System flowchart is the pictorial representation of functional parts of a computer system. The sequences of execution of tasks are being elaborated by the use of a flowchart. For the purpose of this project, below is the flowchart of the envisaged system.

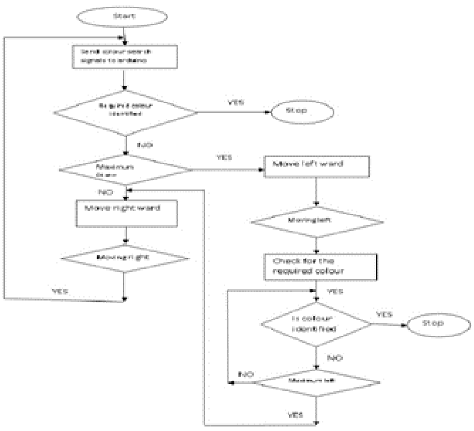

Fig 8: Flowchart of the Envisaged System

Algorithmic State Machine (ASM) method is a method for designing finite state machines. It is used to represent diagrams of digital integrated circuits. The ASM diagram is like a state diagram but less formal and thus easier to understand. An ASM chart is a method of describing the sequential operations of a digital system.

In many cases just drawing a state diagram includes certain assumptions that are not true in general. Perhaps certain cases of inputs will never happen, hence the corresponding arcs are simply not drawn. Certain cases of outputs are not significant and sometimes are left out. An algorithmic state machine (ASM) diagram offers several advantages over state diagrams:

- For larger state diagrams, often are easier to interpret
- conditions for a proper state diagram are automatically satisfied
- may be easily converted to other forms

A key point to remember about ASM charts is that given a state, they do not enumerate all the possible inputs and outputs. Only the inputs that matter and the outputs that are asserted are indicated. It must be known whether a signal is positive or negative logic.

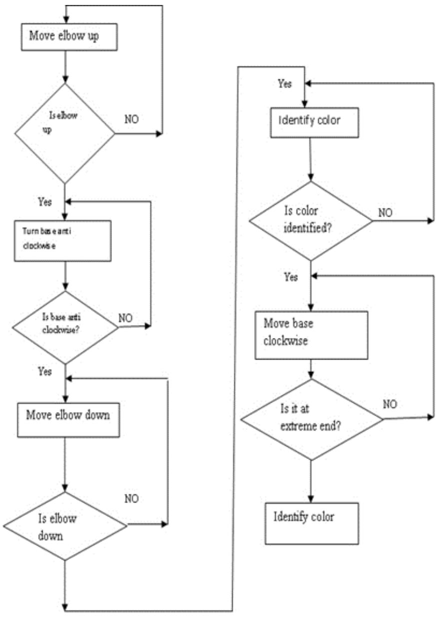

Fig.9 Algorithm State Machine Chart

VI. System Testing And Integration

System Testing

System testing of hardware and software is a block testing techniques performed to evaluate the complete system, the system`s compliances against specified requirement. In system testing the functionality of the system are tested from end-to-end perspective. It is usual carried out by a team that is independent of the development team in order to ensure the quality of the system unbiased. It includes both functional and non functional testing. At the completion of every project, system testing needs to be carried out to guarantee that the project is working effectively.

Unit Testing

Unit testing is a method use in testing the software and hardware components individually (in models). The sets of computer program modules together with the control data, usage procedures, operating procedure and source code are tested to determine whether they are fit for use. The hardware components like the relay model, Arduino Uno, the TSC3200 programmable sensor are tested separately to determine their individual functionality before integrating them to the robot arm to form a complete system. Ideally, each test case is independent from the others. Unit tests are typically used by software developers and hardware designer to ensure that it meets its design and behaves as intended. Unit testing method was use in this project to test for the individual component used in constructing the robot arm. The goal of unit testing is to isolate each part of the component and show that the individual parts are tested and are working in its appropriate condition.

Unity testing offer some benefiters

Finds problems early

Unit testing finds problems early in the development cycle for example in the development software. The cost of finding a bug before coding begins or when the code is first written is considerably lower than the cost of detecting, identifying, and correcting the bug later; bugs may also cause problems for the end-users of the software. Any hardware found malfunctioning will be changed early before the start of the design.

Facilitates change

Unit testing allows the designer upgrade system at a later date, and make sure the module still works correctly. Unit tests detect changes which may break a design contract.

Simplifies integration

Unit testing may reduce uncertainty in the units themselves and can be used in a bottom-up testing style approach. By testing the parts of a program first and then testing the sum of its parts, becomes much easier.

Documentation

Unit testing provides a sort of living documentation of the system. Developers looking to learn what functionality are provided by a unit, and how to use it, can look at the unit tests to gain a basic understanding of the unit's interface

Software Testing

Software testing involves the execution of a software component or system component to evaluate one or more properties of interest. In general, these properties indicate the extent to which the component or system under test meets the requirements that guided its design and development;

- responds correctly to all kinds of inputs,
- performs its functions within an acceptable time,
- is sufficiently usable,
- can be installed and run in its intended environments
- Achieves the general result its stakeholders desire.

Integration Testing

Integration testing is any type of testing that seeks to verify the interfaces between system components against a software design. Integration test is considered a better practice since it allows interface issues to be located more quickly and fixed.

Integration testing works to expose defects in the interfaces and interaction between integrated components (modules). Progressively larger groups of tested software components corresponding to elements of the architectural design are integrated and tested until the software works as a system (Beizer et al 1990). The test result of the direction movement of the micro computer controlled color identification robot arm is show in the table 6.

Table 6: Test Plan and Test Result of the System

S/N	Events	Expected Result	Actual Result
1.	Click on Turn Base left and identify color	Robot Base to Turn extreme left	Robot Base Turned extreme left and color identified
2.	Click on Turn Base right and identify color	Robot Base to Turn extreme right	Robot Base Turned extreme right and color identified
3.	Click on Turn Elbow Up	Robot Elbow to Turn Up	Robot Elbow Turned Up
4.	Click on to Turn Elbow Down	Robot Elbow to Turn Down	Robot Elbow Turned Down

Testing Methods

The test method adopted for the testing of the Micro-Computer controlled color identification Robot arm is the Modularization Method of testing. This method was adopted so as to carry out a test on each of the modules before carrying out a test on the whole system. A test was carried out on the control circuit, in modules as each module (comprising of a four module relay, Arduino Uno) is expected to behave in a certain manner. This test was to make sure that each of the modules is in good condition and also to enable correction of the likely errors beforehand. This mode of testing is also referred to as one-on-one test. After each of the modules of the control circuit has been tested, the circuit was connected to the computer system with the use of the Universal Serial Bus (USB) and a software test was as well carried out on the system. The software test was as also done in modules as each of the modules of the software is supposed to control one module of the control circuit.

As the control circuit and software tests has been completely carried out and verified to be working properly, the robot arm was attached to the circuit so that a complete test of the system will be performed.

During the whole system testing, it was discovered that the robot arm performed as intended since the control software was able to put to robot to work (indentify the three primary color Red, Blue and Green) as it was executed.

In conclusion as regards the test, this modular method of testing was very helpful as it enabled smaller units of the project research to be tested first before the whole system was tested. The test method as well helped in fixing the errors that were discovered in modules and as such, eliminated the errors during the whole system testing.

VII. Summary, Conclusion And Recommendations

Summary of Achievement

A robot is defined as a programmable, self-controlled device consisting of electronic, electrical, or mechanical units. This paper presents the design, development and construction of a robot arm, which can identify objects of different colors (red, green and blue). The mechanical structure of the robot was assembled and attached with some components like the DC motor which aid the movement in four degree of freedom and the Color Sensor TCS 3200 that have the full function of identifying different colors. The control circuit includes Arduino Uno which as an interface between the control circuit and computer system. It also aid in transmitting and receiving of data from the computer. The Four relay module relay is responsible for the angular movement of the motor and a power source that supply power to the relay from the power pack of a computer system. The control software is an interface between the use and the robot arm. The aim of the project was to have a fully functional micro computer controlled color identification robotic arm, which identify objects of different colors and the target was achieved successfully. In the final run of the project red, blue and green colors were successfully identified.

Problems Encountered and Solution Adopted

In this short section, we hope to provide to researchers outside robotics with some insight into where the difficulties in building these robots exist. In the design of microcomputer controlled color identification robot arm from the practical perspective, it is an enormous investment of time, engineering, money, and effort. Maintaining these systems can also be a frustrating and time-consuming process. Furthermore, to build all of these systems to operate in real time requires an enormous dedication to building computational architectures and optimized software.

The TCS3200 color sensor when testing it was revealed that one of the LEDs out of the three is not blinking, fortunately after browsing through the manual of the device it was discover that it is a normal phenomenon this did not affect the output. The color sensor TCS3200 show almost unstable response in various sunlight conditions sometimes the input data will vary depending on the intensity or brightness of the environment.

Partial contact on the board was discovered as a result of inappropriate wire connection and bad soldering together of the digital pin of the Arduino Uno and the relay pin module. The solution proffered to this was to dismantle and reconnect the wires where the contacts were discovered. On doing this, the system was performing well.

The system was generating a back Electro Motive Force (EMF) as a result of the continuous execution of the software even when the robot's base has reached its final turning point. This caused the connecting wires to generate excessive heat causing damage to the wires and system in general. When this was discovered, a switch was used to control the movement of the arm. The arm stops when it has moved to the final turning point though the software still sends logic.

Conclusion

This project involves identification of objects through colour sensor and replacing human labor with robot. The research project successfully carries out the task of identifying the colour of object at the pre programmed work place. This method is verified to be highly beneficial for Nigerian automated industries. The sensor is key component of project which aides in distinguishing the objects. Failing of which may result in wrong color sorting handling. Thus it becomes vital that the sensor had a very high sense of sensitivity and ability to distinguish between colours.

Recommendations

After the course of this research, a reliable and efficient Micro Computer Controlled color identification Robot Arm was constructed using a high technology components and a friendly, ease to use software enough to relieve, reduce and minimize the difficulties encountered with the colors identification of materials especial in Agriculture Industries. Therefore, it is recommended that this system be adopted for use in identification of colors to ease the enormous stress and cost posed by the manual method of identification.

The color sensor TCS3200 show almost unstable response in various sunlight conditions. A better resolution can be achieved if an illuminate sensor called TSL2591 High Dynamic Range Digital Light Sensor, is incorporated to the robot to increase the amount of light captured and thereby improves low-light performance

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