A Model of Magnetic Material Separating Robot

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Abstract – Every aspect of human endeavor is being controlled by computing and the application of computers in solving human needs has enhanced man's performances. No doubt, as other areas of computing (Networking, Database administration, software engineering, web design, etc) delve into critically solving human basic problems, the area of Robotics and Artificial Intelligence is not left out as well. In material separation, different particles of varying degree are being separated with different separating mediums. Magnetic materials can be separated from non-magnetic materials and that is the sole basis of this research project. Humans find it difficult to separate magnetic materials from non-magnetic materials due to the fact that there is limited equipment that can handle the automatic material separation available in some places. The Magnetic Material Separating Robot Arm is a robot that is capable of making four movements (clockwise, anticlockwise, upward and downward movements), to enable it move the arm to the direction of the metal, pick some of the materials and drop them in a collecting provision that has been made. In an age where the need for automated systems is on the increase, automated system developers will have to put more effort to see that the need is being met. Meeting the needs of computer automation as well as taking into consideration some precautionary measures is very vital when it comes to automated system development. As in the case of the killer robot, the machine malfunctioned and got an operator killed due to negligence on the side of the system designers; the wrong methodology was adopted and instead of the robot working in favour of humans, it got the operator killed. This paper discusses the steps involved in the design of magnetic material separating robot which is fully computer controlled, the interfacing circuit and control software.

Index Terms – Robot, Micro-computer, Magnetic Material Separation, Robot arm.

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1 INTRODUCTION

The industrial robot has become the standard bearer for the manufacturing automation movement. It is partly responsible for changing the way in which products are manufactured today. The use of the industrial robot has resulted in the increased attention given to product design to facilitate orientation, positioning and mating of assembly production. Robots are also much more versatile than the human operators they are replacing, as well as more efficient in many ways. Where safety is a factor, the use of the robot is preferred because more time can be spent on the manufacturing instead of dealing with personal protective equipment. Also, robots are more efficient where the parts to be handled are hot or extremely heavy. Therefore, there is a place for robots in industry and increasing applications are being explored for these programmable machines.

Robots are indispensable in manufacturing industries. The reason is that the cost per hour to operate a robot is a fraction of the cost for human labor needed to perform the same function. More than this, once programmed, robots repeatedly perform function with a high degree of accuracy that surpasses that of the most experienced human operator. Human operators are, however, far 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.

Robots are in the infancy stage of their evolution. As robots evolve, they will become more versatile, emulating the human capacity and ability to switch job tasks easily.

While the personal computer has made an indelible mark on society, the personal robot hasn't made an appearance. Obviously there's more to a personal robot than a personal computer robots which require a combination of elements to be effective: sophistication of intelligence, movement, mobility, navigation and purpose.

This research is focused mainly on the development of a robotic arm that is designed to have four degree of movement; upward, downward, clockwise and anticlockwise, separating and transferring magnetic material from non magnetic material. The separating transducer is solenoid which is attached to the robot arm. The circuit component includes relays, Integrated Circuits (ICs) and opto-couplers. The arm is powered by two Direct Current (DC) motor. These motors are interfaced with the computer where the movement of the robot arm is controlled by using the computer keyboard to input the angle and direction of motion. In this particular project, Programmable Interrupt Controller (PIC) microcontroller is programmed into the instructions to control the servo motor. Robotic arm is a type of

mechanical arm, usually programmable, with similar functions to a human arm.

Types of robot arms depend on their range, working capability and reach. Cartesian robot is used for pick and place work, plotting and handling arc welding. Its range is mostly 2 dimensional. Cylindrical robot is also used for the above mentioned working categories, but since it operates in a cylindrical co-ordinate system, it can be used to do the operations more precisely and accurately. Furthermore, it also has a wider reachable range. Spherical robot works on the polar coordinate system. SCARA robot is mainly used for pick and place work. It has two parallel rotary joints to provide flexibility in a plane. Then for a three dimensional reach it is usually combined with other mechanisms. Articulated robot has three rotary joints. Parallel robots are used in the mobile platform handling cockpit flight simulators. It is a robot whose arms have concurrent prism shaped or rotary joints. Anthropomorphic robot resembles a human hand, with independent fingers and thumbs.

2 ROBOT

Robots have their historical past though they came into existences only in 1961 when Unimation Inc, USA introduced the first servo-controlled industrial robots. Early development dating back to 500B.C shows that the Egyptians, Indians, the Chinese, and the Romans built many automatic puppets which imitate the movement of animals and birds. The Chinese built many amusing devices that depicted sequential motions. Also, the early men discovered many mechanisms and exhibited their innovation skill in building ships and introduced looms to weave. This ushered in the industrial revolution. In the 1940s, remote teleported master- slave manipulators were developed. Later, force feedback and kinesthetic sensory elements were added to them to facilitate better control. Tele-operated devices were used in mars exploration in 1976. In 1948, the transition was invented at Bell laboratories U.S.A. In 1952, IBM's first commercial computer IBM 701 was introduced. Then came numerically controlled tools in which various slides of machines were displaced by numerical commands through suitable hardware. The development of NC (numerically controlled) machine tools has, therefore, been a turning point in the development of robotics.

A robot is a general term that stands for automated unit which does have some kind of human symbolization in its operation of physical structure [1]. It is an "intelligent" manmade device that can move by itself, whose motion can be modeled, planned, sensed and controlled, and whose motion and behavior can be influenced by programming. A robot is a general purpose, programmable manipulator. In practice it is usually an electro-mechanical system which by its movements and appearance conveys that it has intent of its own. Today, commercial and industrial robots are in widespread use, performing jobs more cheaply or with greater accuracy and reliability than humans. They are also employed for jobs that are too dirty, dangerous or boring to be suitable for humans. Robots are widely used in manufacturing, assembly and packing, earth and space exploration, surgery, weaponry, laboratory research and mass production of consumer and industrial goods. As robotic technology develops and becomes cheaper domestic robots for cleaning or mowing the lawn are available, along with robotic toys for children of all ages. When we talk about robots, what we are really talking about is machines that will do what human beings would normally be expected to do [2]. These machines mimic the operation of the human being or at least certain parts of it. Most shop floor robots are the emulation of one arm of a human.

➢ Their motors are the muscles.
➢ The general purpose computer represents the human brain.
➢ Robotic vision represent the eye

We combine these various elements in different ways to create the robot that we require. The most common robot used in industry today is the robot arm. These arms are used to weld, package, paint, position and assemble a host of products that we use daily. Basically a robot arm is a series of linkages that are connected in such a way that a servo motor can be used to control each joint. The controlling computer, the brain of the robot, is programmed to control the various motors on the robot in a way that allows it to perform specific tasks.

The robot arm can be designed in a number of different ways, the size and shape of this arm is critical to the robotic architecture of the robot [3]. The arm is the part of the robot that positions the final grabber arm or spray head to do their pre-programmed business. If the design of the arm is too

large or small this positioning may not be possible. Many arms resemble the human arm, containing shoulders, elbows wrists and hands. The design of the human arm is exceptional and allows for precise and complicated movement. As a rule you need one motor for each degree of freedom that you want to achieve. A degree of freedom is typically one joint movement [4]. So a simple robot with 3 degrees of freedom can move three ways: up and down, left and right, forward and back. This simple pan and tilt robot has 2 degrees of freedom, powered by two servo motors. It can rotate left to right and lift up and down. Many robots today can be designed to move with 7 degrees of freedom.

2.1 Laws of Robot

The word robotics comes from "Runaround", a short story published in 1942 by Isaac Asimov. One of the first robots Asimov wrote about was a robo-therapist. A Massachusetts institute of technology professor, Joseph Weizenbaun, initially programmed Eliza program in 1966, a modern counterpart to Asimov's fictional character. Weizenbaun initially programmed Eliza with 240 lines of code to stimulate a psychotherapist. The program answered question with question.

Asimov created the four laws of the robot behavior, cyber laws that all robots had to obey and a fundamental part of poistronic robot engineering. Asimov claimed that they were originated by John W. Campbell in a conversation they had on December 23, 1940. Campbell in turn maintained that he picked them out of Asimov stories and discussions, and that his role was just to state then explicitly. The first story to explicitly state the three laws was "Runaround", which appeared in March, 1942 issue of "Astounding Science Fiction". Unlike the Three Laws, however, the Zeroth law is not a fundamental part of positronic robotic engineering is not part of all positronic robots and in fact require a very sophisticated robot to even accept it [5].

➢ Law Zeroth: A robot may not injure humanity or through inaction allow humanity to come to harm.

➢ Law one: A robot may not injure a human being or through inaction allow a human being to come to harm unless this violate a higher order law that is the zeroth law.

➢ Law two: A robot must obey orders given to it by human beings except where such orders would conflict with a higher order law that is the first two laws.

➢ Law three: A robot must protect its own existence as long as such protection does not conflict a higher order law that is the two laws.

2.2 Robotic Arm

Robotic arm is a type of mechanical arm, usually programmable, with similar functions to a human arm. Types of robot arms depend on their range, working capability and reach.

2.3 Degrees of Freedom of Robot Arm

The following will demonstrate the degrees of freedom using the human arm [6].

➢ **First Degree: Shoulder Pitch**
  Point your entire arm straight out in front of you. Move your shoulder up and down. The up and down movement of the shoulder is called the shoulder pitch.

➢ **Second Degree: Arm Yaw**
  Point your entire arm straight out in front of you. Move your entire arm from side to side. This side to side movement is called the arm yaw.

➢ **Third Degree: Shoulder roll**
  Point your entire arm straight out in front of you. Now, roll your entire arm from the shoulder, as if you were screwing in a light bulb. This rotating movement is called a shoulder roll.

➢ **Fourth Degree: Elbow Pitch**
  Point your entire arm straight out in front of you. Hold your arm still, and then bend only your elbow. Your elbow can move up and down. This up and down movement of the shoulder is called the elbow pitch.

➢ **Fifth Degree: Wrist Pitch**
  Point your entire arm straight out in front of you. Without moving your shoulder or elbow, flex your wrist up and down. This up and down movement of the wrist is called the wrist pitch.

➢ **Sixth Degree: Wrist Yaw**
  Point your entire arm straight out in front of you. Without moving your shoulder or elbow, flex your wrist from side to side. The side to side movement is called the wrist yaw.

➢ **Seventh Degree: Wrist Roll**

Point your entire arm straight out in front of you. Without moving your shoulder or elbow, rotate your wrist, as if you were turning a doorknob. The rotation of the wrist is called the wrist roll. The Crust Crawler Robot has 5 degrees of freedom and is a Revolute Robot.

3 SYSTEM COMPONENTS
3.1 4N35 IC (Optocoupler)

The 4N35 is an opto-coupler for general purpose photo-coupler applications. It contains a light emitting diode optically coupled to photo transistor. It is packaged in a 6-pin D.P package and lead and available in wide lead spacing option and lead bend SMD option. Response time is typically 3 US and minimum is 100% at input current of 10mA. 4N35 opto-couplers is packaged as a Dil-6 package. The little component has 6 legs each of them having a different usage it can be easily understood while looking at the following pictures from the 4N35 data sheet which shows us the inside schematic of 4N35.
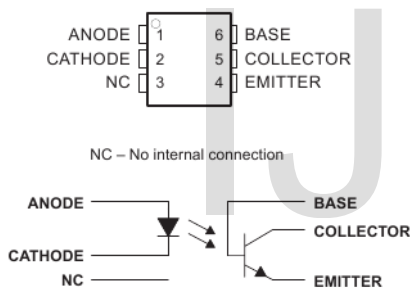

Figure 1: 4N35 Opto-couplers with connecting points arrangement

Leg1 and leg2 near the printed dot on the chip (that's visible on it if we look carefully) that act respectively as anode and cathode. Leg3 isn't connected to anything. It is just useless. Then leg 4, 5 and 6 are emitter, collector and base respectively.

3.2 DC Motors

These are the most common motors available, connected to a power supply by two wires. The direction of a DC motor can be changed by reversing the polarity of the motor supply voltage. DC motors draw a large amount of current and as a result cannot be wired straight from a control system such as PIC. DC motors do not offer accurate, controlled rotation. At the most basic level, electric motors exist to convert electrical energy into mechanical energy. This is done by way of two interacting magnetic fields -- one stationary, and another attached to a part that can move. A number of types of electric motors exist, but most BEAM bots use DC motors in some form or another. DC motors have the potential for very high torque capabilities (although this is generally a function of the physical size of the motor), are easy to miniaturize, and can be "throttled" via adjusting their supply voltage. DC motors are also not only the simplest, but the oldest electric motors. The basic principles of electromagnetic induction were discovered in the early 1800's by Oersted, Gauss, and Faraday. An electric current produces a magnetic field. The next 15 years saw a flurry of cross-Atlantic experimentation and innovation, leading finally to a simple DC rotary motor. A number of men were involved in the work, so proper credit for the first DC motor is really a function of just how broadly you choose to define the word "motor."

3.3 Principles of Operation of a Modern DC Motor

In any electric motor, operation is based on simple electromagnetism. A current-carrying conductor generates a magnetic field; when this is then placed in an external magnetic field, it will experience a force proportional to the current in the conductor, and to the strength of the external magnetic field [7]. As you are well aware from playing with magnets as a kid, opposite (North and South) polarities attract, while like polarities (North and North, South and South) repel. The internal configuration of a DC motor is designed to harness the magnetic interaction between a current-carrying conductor and an external magnetic field to generate rotational motion. Let's start by looking at a simple 2-pole DC electric motor (here red represents a magnet or winding with a "North" polarization, while green represents a magnet or winding with a "South" polarization). Every DC motor has six basic parts -- axle, rotor, stator, commutator, field magnet(s), and brushes. In most common DC motors, the external magnetic field is produced by high-strength permanent magnets.
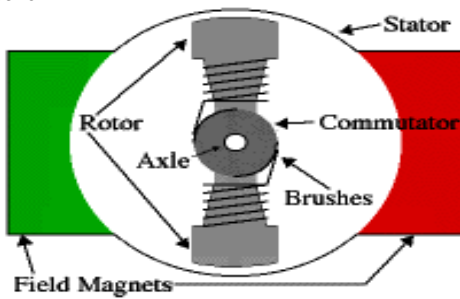
Fig. 2. Structure of a Modern DC Motor.
Source: Google images (2015).

4 METHODOLOGY AND SYSTEM ANALYSIS
4.1 Methodology

The Systems Development Life Cycle (SDLC) provides the foundation for the processes used to develop an information system [8]. A methodology is a formalized approach to implementing the SDLC (i.e., it is a list of steps and deliverables). There are many different systems development methodologies, and they vary in terms of the progression that is followed through the phases of the SDLC. Some methodologies are formal standards used by government agencies, while others have been developed by consulting firms to sell to clients. Many organizations have their own internal methodologies that have been refined over the years, and they explain exactly how each phase of the SDLC is to be performed in that company. Here we will review several of the predominant methodologies that have evolved over time.

4.1.1 Modularization Approach

Modularization is the process involved in breaking down of a large system into smaller units called 'sub-modules', so that these subunits will be easy to handle. Each of these sub-modules is handled as a single unit on its own and when all modules are finally completed, the whole project is completed. With modularization approach of system development, large and tedious projects can be easily handled as though it is never difficult. This is because the large project is usually broken down into several smaller units which can be easily handled as separate subprojects. Modularization approach, as a software development methodology is always employed majorly in hardware project development.

The first challenge faced by project managers is to select which methodology to use. Choosing a methodology is not simple, because no one methodology is always best. Many organizations have standards and policies to guide the choice of methodology. You will find that organizations range from having one "approved" methodology to having several methodology options to having no formal policies at all. Therefore, depending on this difficulty in appropriate methodology selection, it is vital to examine different approach before making the decision of the desired approach to be adopted. All the above methodologies discussed are very good methodologies which if any of them is adopted, will help in the design of a wonderful system but for the numerous disadvantages accompanying some of them, there might seem to be problems that will be encountered in the course of the design which will be very difficult to correct at later stage. Therefore, as a result of the basic advantage of the modularization approach which is making a large project easy to handle by breaking it down into smaller units, the design of the computer-based magnetic material separating robot adopts the modularization approach despites its few weaknesses which will not interfere in the course of the system design. This is basically because the control circuit is to be divided into modules which would be handled separately. Each of the modules comprises of two (2) relays, 4N35 ICs and a DC Motor.

4.3 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 automatically attending to separation process. The proposed system fixed this issue as the magnetic material separating robot has control software and an interfacing medium that is made up of relays and ICs. These relays are automatically magnetized and demagnetized thereby causing the arm to move in a clockwise or anticlockwise direction. The other DC Motor that controls the upward and downward movement of the arm is being controlled by the other set of relays and ICs. In all, the control software and the interfacing circuit control the whole of the magnetic material separation. The proposed system also have a solenoid attached to the tip of the arm instead of the

bar magnet. This solenoid, when magnetized, picks magnetic materials and when demagnetized, drops the materials. This method of picking and dropping of magnetic materials makes the magnetic material separating robot to automatically pick and drop materials without the help of an operator. The only work that needs to be done here in the separation process is the starting of the software.

4.4 Hardware and Software Specification

Every system developed has a certain specification of hardware and software that is required for proper functionality. Therefore, Micro Computer Based Magnetic Material Separating Robot, is not an exception to other systems in terms of hardware and software specifications. Below is a summary of the specification that is to be met for any system intended to be used for the control of the magnetic material separating robot.

Table1
Hardware and Software Specification

Hardware Specification	
Component	**Specification**
Processor Speed	750GHz and above
RAM Size	520MB and Above
Hard Disk Size	5GB and above
Video Card	Any video card that can give best resolution
Software Specification	
Operating System (OS)	Windows 98 and above

5 SYSTEM DESIGN AND IMPLEMENTATION

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-based Magnetic Separating Robot. 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, separation of materials with magnetic properties. 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.

In general, the above three components are joined together to make up the complete project capable of automatically separating magnetic materials.

5.1 Structure of the Robot

Just as discussed above 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 separation 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. Below is the view of the robot arm.
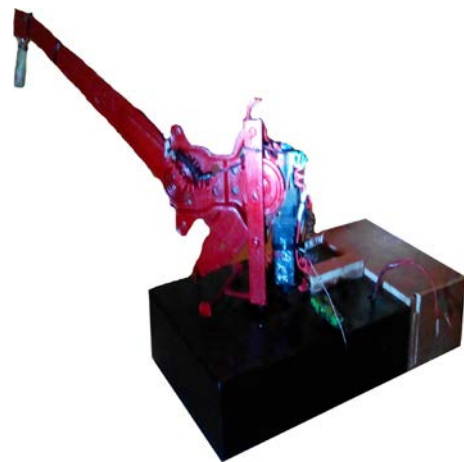

Fig. 3. Magnetic Material Separating Robot Arm

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 etc are attached to the robot. The components

that make up the robot arm includes: effector, gear, DC motor, Switch and transducer.

5.2 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 with two relays and two ICs in one module. Below is the circuit diagram for one module.
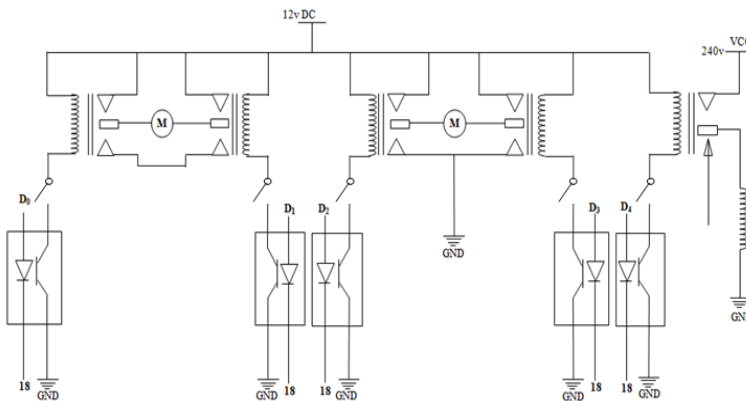

Fig. 4. Circuit Diagram of Interfacing Circuit

In the above diagram, it can be technically seen that there are five (5) relays in all mounted in modules of two relay in one. Each of these relays have a control IC connected directly to it. To elaborate more on the above circuits, the table below shows a description of all the circuit components used in the circuit design. 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; Relay. 4N35 IC (Opto-coupler), Wires and Switches.

5.3 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.
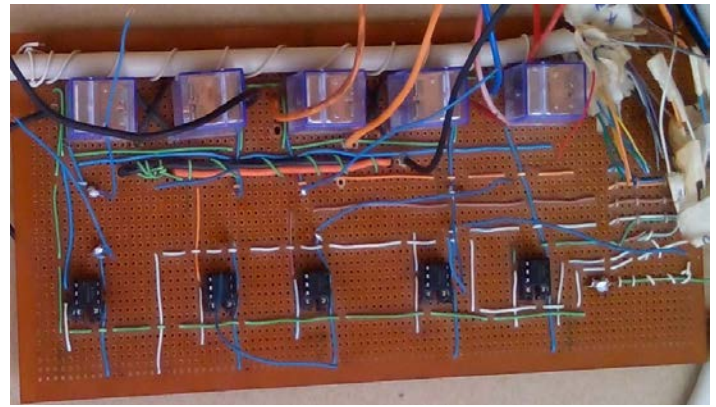

Fig. 5. Layout Diagram of Interfacing Circuit

5.4 System Implementation

This section looks into the various implementation procedures involved during the course of this work. We shall critically look at the system implementation under the following headings

5.5 Choice of Implementation Language

The choice of programming language used in the design of the control software is Visual Basic 6.0. The choice of this programming language is due to the Direct Link Library (DLL) which is in charge of creating a link between the hardware (printer port) and the control software developed using visual basic. There are only two windows operating system, Windows 95 and windows 98 that can use Direct Link Library (DLL) module. For this project Windows 98 was used.

5.6 Block Diagram of the Envisaged System

A block diagram is a pictorial representation of the cause and effect relationship between the input and out of a physical system. It provides a convenient and useful method for characterizing the functional relationships among the various components of the control system. The block diagram of the micro computer based magnetic material separating robot shows the relationship and flow of signal among the various component of the system. From the block diagram 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

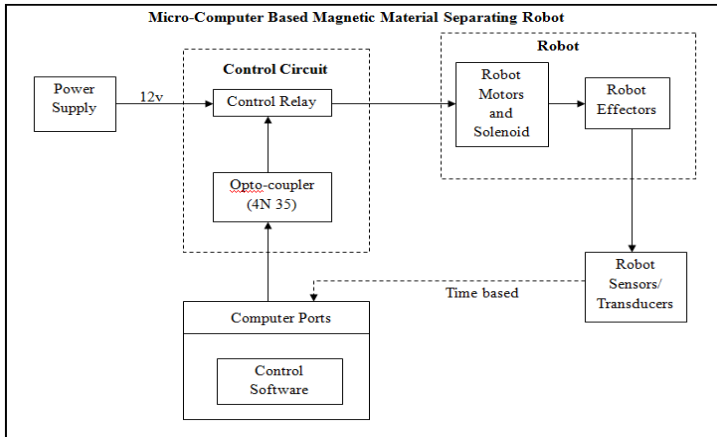control circuit, the signal is sent to the robot motors and solenoid. The block diagram is as shown below

Fig. 6. Block Diagram of the System

5.7 System Flowchart

System flowchart is the pictorial representation of functional parts of a computer system. The sequence 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.
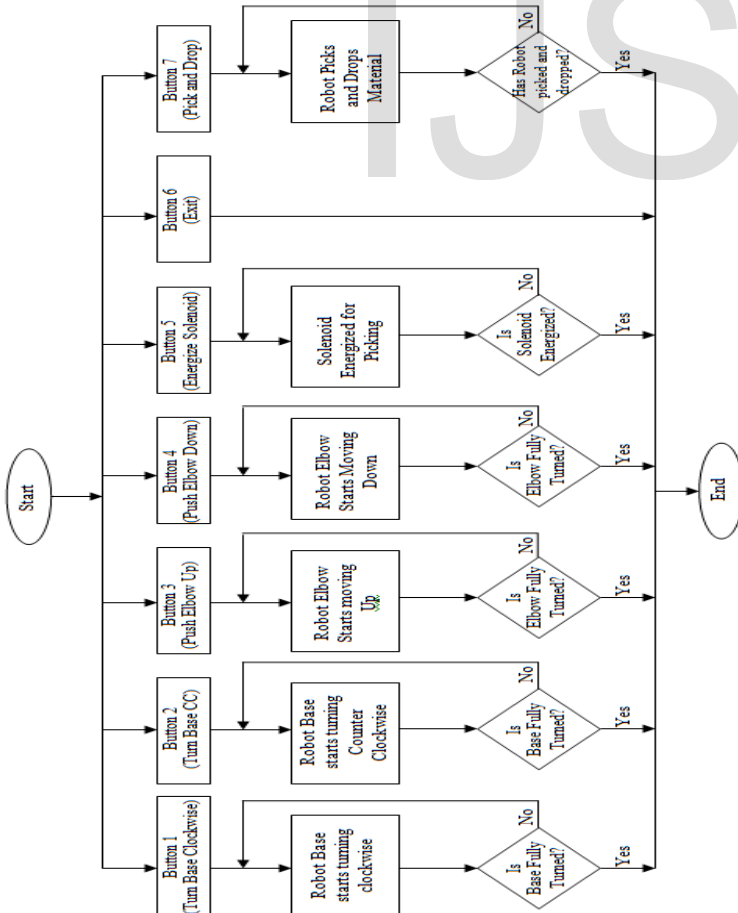

Figure 7: Flowchart of the System

In every hardware project, the issue of making appropriate calculation for the input and output port manipulation is very vital. In the course of this project, the appropriate mathematical calculation was carried out and the result of the calculation was summarized for easy understanding of the port addresses to be used. Table 4 in the, appendix shows a summary of the calculation for the input and output port manipulation.

Table 2
Summary of calculation for Output Port Manipulation

		16	8	4	2	1	
		2^4	2^3	2^2	2^1	2^0	
		Solenoid	EDown	EUp	BCC	BC	Values
1.	No Action	0	0	0	0	0	0
2.	Turn Base Clockwise	0	0	0	0	1	1
3.	Turn Base Counter-Clockwise	0	0	0	1	0	2
4.	Push Elbow Up	0	0	1	0	0	4
5.	Push Elbow Down	0	1	0	0	0	8
6.	Energize Solenoid to Pick	1	0	0	0	0	16
7.	Pick and Move Elbow Up	1	0	1	0	0	20
8.	Pick and Turn Base Clockwise	1	0	0	0	1	17
9.	Pick and Drop						
	Move Elbow Down	0	1	0	0	0	8
	Energize the Solenoid	1	0	0	0	0	16
	Move Elbow Up	1	0	1	0	0	20
	Turn Base Clockwise	1	0	0	0	1	17
	Move Elbow Down	1	1	0	0	0	24
	De-Energize Solenoid	0	0	0	0	0	0
	Move Elbow Up	0	0	1	0	0	4
	Turn Base Counter-Clockwise	0	0	0	1	0	2

6 SYSTEM TESTING

System testing of software or hardware is testing conducted on a complete, integrated system to evaluate the system's compliance with its specified requirements. As a rule, system testing takes, as its input, all of the "integrated" software components that have passed integration testing and also the software system itself integrated with any applicable hardware system(s). If at the end of every project, be it software or hardware, and system testing is not included, the project is not yet complete.

6.1 Summary of Achievement

With micro computer based magnetic material separating robot, industries that are aimed at separating magnetic material from non magnetic are relieved from the expenses of employing human labor which are quite expensive. Also the long delay and mistakes associated to human labor as a result of fatigue is ruled out because robots are more efficient than human. To control the robot arm movement a circuit was designed with 2 DC motors and 4n35 Optocouplers that are connected to the computer through the parallel port and controlled by a program written in visual basics 6.0. This project has exposed us to the processes involved in robot arm development and industrial separation of magnetic material. The project was practical based, interactive and user friendly hardware that is fully implemented with all the specified functionalities.

6.2 Application Areas

Magnetic material separating robot has its major area of application in the automobile assembling industry, waste management industry and steal production industry.

6.3 Problems Encountered and Solution Adopted

During the course of the design of this magnetic material separating robot, several challenges and problems were encountered, as it is always the case for every project. In building a hardware project, at the point of interfacing, there seem to be errors if any of the connecting points is wrongly connected. Also, the serial port of the printer, if any of the pin is damaged, could lead to the malfunction of the system. This was the case in this project work and as it was detected that one of the connecting pins of the printer port is bad, the computer board was totally replaced with a new one to avoid encountering problems in the future.

In the design of this project, several challenges were encountered especially at the testing stage. The different modules when tested in modules without the opto-couplers connected, perfomed very excellently but on insertion of the opto-couplers, it was discovered that only one of the modules was active and it was over riding other modules. Other modules couldn't switch as a result of a partial contact on the board at the input pin of the IC. There seemed to be points which were not meant to have a contact, connecting with each other. The solution proffered to this was to dismantle and reconnect the IC where the contacts were discovered. On doing this, the system was performing well.

Also, the system was generating a back EMF (Electro Motive Force) 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 1. The addition of the switch was to control the movement of the base so as to control the movement of the arm.

7 CONCLUSION

The objective was to build a robot that will improve the efficiency in magnetic material separation, replacing human labor with robot. In building this robot, a survey of robot arm and magnetic material were made. After this, the actual design of the robot arm was carried out and a solenoid was attached to the tip of the arm for the magnetic separation. The design of the interfacing circuit and control software was also carried out. Nigerian (and general automation) industries should realize the economic feasibility of automated systems. It will be worthwhile if more interest is developed in the new era of automated systems in order to gain numerous advantages of computer operation.

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