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MENG411 Capstone Team Project

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Sliding Robot

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ABSTRACT

Distributed system is defined to be a system that is made up of different components in a network that communicate in order to achieve a common goal. The system is distributed which means it is considered as nodes that every node is an object (robot, station, storage and etc.) working independently and in collaboration with each other. Robotic arms have proved to be very advantageous in industry. They are an important part in Material Handling Systems and in collaboration of nodes in intelligent manufacturing system. Material handling makes up 10% to 80% of the cost of a product. The aim of this project is to enable a robotic arm to slide between a conveyer belt, creating a shortcut, thus increasing efficiency by reducing waiting time between stations and making a distributed intelligent system. This has been achieved successfully with minimum friction with a set of gears attached to belts and rollers and driven by a motor. Python programming was used with an Arduino board as a controller. Testing was performed and the results show that the system is working correctly. A 12V motor was used to translate rotational motion into linear motion and it gave 13 W powers.

Keywords: Distributed system, intelligent system, nodes, Material handling system,Robotic arm, conveyers, sliding base

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LIST OF SYMBOLS

A: cross sectional Area

Pe: Electrical power

Pm: Mechanical power

R: Resistance

V: Voltage

Ω: Speed

P: Density

Kt: Torque constant

Ke: Voltage constant

T: Torque

EMF: Electromotive Force

MHS: Material Handling System

FMS: Flexible Manufacturing System

NFC: Near Field Communication

CHAPTER 1

INTRODUCTION

In this chapter an introduction will be given about thiscapstone project and discuss a current versionand propose an improved solution. What was used and what was applied to come up with this solution will be mentioned. The aim of the current system will also be provided.

1.1What isMaterial Handling?

A materialhandling system can simply explained as an integrated system involving activities such as handling, storing, and controlling of products during a manufacturing process.
The essential goal of utilizing a material handling system is to guarantee that the material in the right amount is securely delivered to the correct destination at the right time and with minimum cost.Material Handling and logistics are costly operations which involve 10 % to 80 % of the product cost and this rate has a tendency to climb. Physical distribution alone, i.e., the development of items from the assembling plants to the clients, represents 25 % of the item cost. Inside to the plants, more than 90 % of the product flow time in a workshop is used in material handling functions including waiting for an available machine [1]. Therefore a tendency to decrease the time of the process exists at any manufacturing process as long as increasing efficiency and decreasing the cost is the main aim of each company. Hence engineers are always looking for a way to decrease the time and cost of material handling process since it is the main part of a manufacturing process.

A material handling system consists of conveyors, handling robots, automated storage andretrieval system (AS/RS) and automated guided vehicle(AGV). Conveyer belts are the transportation medium. All these systems are integrated in a way to guarantee a secure, fast and inexpensive process. Among the different material handling systems, conveyor is the one that products spend most of the time of the process on, because the industrial conveyors have long length and also products might face a busy station which makes them wait behind the products that are under a process. Therefore any new technology or idea to decrease the time of this process will be valuable.

The current situation of this project is that there is a conveyor which is going to have two or three stations that perform different tasks and if any of these stations is busy, it will take the time of the other stations by holding their products.

1.2 Problem Definition:

There is a conveyer in the lab that consists of different stations. As workpieces move along the conveyer they enter the stations and each station has a different manufacturing process. If a workpiece was moving along the conveyer and it encounters a busy station, it would have to wait until that station is empty again to pass through. This takes up a long time during manufacturing and wasting time is not economical in industry. A method had to be found to prevent this time delay from occurring.

1.3 Project Aim:

The aim of this project is to create a sliding robot arm, to reduce the processing time, which will be mounted on a platform in the middle of the conveyer allowing the robot arm to move linearly across the conveyer. A motor will be used to translate rotational motion into linear. This will achieve a faster and more efficient operation of 'pick and place' process rather than the usual stationary robotic arm. In the normal operation of conveyer belts, a lot of different parts would be moving on them, so at some point a certain part might encounter a busy workstation. Normally the part would 'wait' until the workstation is empty so it can pass through, but the objective of this project is to make a shortcut for this part across the conveyer to the other side.

The materials to be used and properties such as friction should be taken into consideration. This is important because the result should be a suitable speed and a lower consumption of energy due to low friction.

In this report, an explanation will be provided about the background of material handling systems, conveyers and its control system including the controller that will be used, which will be in the literature review. In the design chapter, the chosen materials and mechanisms will be discussed for the sliding base as well as the control method of the base. Finally this report will provide appropriate conclusion as well as the timetables; figures and programming used which will be attached in the appendices.

CHAPTER 2

LITERATURE REVIEW

2.1Flexible Manufacturing Systems:

A Flexible Manufacturing System (FMS) is a group of numerically-controlled machine tools, interconnected by a central control system. The numerous machining cells which are called flexible manufacturing cells are connected through loading and unloading stations, by a transport system like a conveyer. Operational adaptability is improved by the capacity to execute all manufacturing tasks on various parts in little amounts and with quicker conveyance. Today, this prospect of mechanization and adaptability shows the likelihood of creating nonstandard parts further creating a competitive edge. The general goals of a FMS are to approach the efficiencies and economies of scale ordinarily connected with large scale manufacturing, and to keep up the adaptability needed for little and medium size production of various parts [2].

2.2The History of Material Handling System:

2.2.1 Conveyor:

For over 100 years, conveyor systems have been a crucial part of material handling, and their origins can be tracked back even further than that. Conveyer belts were transporting bulk material since 1975 but in these early times they were mostly use to move grans over short distances.

The early conveyer belt systems were very simple. They had a leather, canvas or rubber belt travelling on a flat wooden belt. The success of this system motivated engineers to start researching and come up with a way to transport bulk material over large distances.

During the 20th century in Minneapolis-St Paul area, conveyers were used to retrieve wooden shingles from rail cars. Before long, conveyers were consistently utilized for different applications too and overhead trolleys and belt conveyers were moving parts in assembling plants.

Hymle Goddard of Logan Company got the first patent for roller conveyer in 1908, yet the transport business didn't positively thrive until a couple of years after that. Automotive manufacturing used controlled and free conveyer lines starting in 1919, and all through the 1920s, conveyers turned into a famous instrument for taking care of mass created products inside industrial facilities.

Amid the 1920s, conveyers were created that could convey things over longer distances. One especially interesting system was built underground to handle runs of mine coal over a length of eight kilometers. This conveyer belt was made out of layers of cotton and elastic covers, the fundamental materials to making a belt at that time. Albeit obsolete by today's standards, this material handling system was chosen rather than railcars in numerous mining applications.

Nowadays the largest conveyer belt is 60 miles long located in Western Sahara's phosphate mines.

During the Second World War, manufacturers made engineered materials to make belting due to the shortage of regular parts. Today's transport belting is produced using a very nearly infinite list of manufactured polymers and fabrics and can be custom-made to any necessities. Ever since the old days, the applications of conveyers have extensively grown and are used in almost any industry where materials must be taken care of, put away or retrieved[3]. In figure 2.1, a sample of the primary belt conveyor is illustrated which shows that material handling processes had a particular importance even at 19th century.

Figure 2-1- Old conveyors 1971[4]

A safety guide had to be developed since moving materials in an industrial environment might have significant dangers. Therefore the Americans Standards Association came up with the first safety standards. They became dedicated to ensure safe operations and spread safety awareness to the whole world to reduce any chance of accidents.

There was a high noise problem with conveyers in the 1970s. That's why it became one of the most important things for manufacturers of belt systems, to reduce conveyer noise. They started creating quiet rollers and precision bearings and components that would last long to reduce any early corrosion that would cause friction and disturbing noise.

Maintenance and system control were subject to improvement. It used to be difficult to maintain and service conveyers because they were created in a permanent way without any flexibility. Taking care of this would have been very costly and time consuming. A lot of times the whole system would be replaced with a new one just because of a small fault, way before the expected life of the conveyer system. The solution achieved by the engineers during the late part of the 20^{th} century was mastering motorized pulleys and internally powered conveyer rollers. This reduced the cost of maintenance significantly.

Material handling systems have kept growing in research fields with new and innovative designs along with technological improvements. Computers are now controlling very complicated applications with more precision and efficiency.

Our world is changing at a fast pace and new technologies are being developed every day, that's why industries should keep working on improving current designs as users seek faster throughput, diverted sorting and use of wireless technologies.

A general belt conveyor system comprises of two or more gear, with an endless loop of carrying medium—the conveyor belt—that rotates about them. One or both of the gears are poweredusing a motor, moving the belt and the material on the belt forward. The powered gear is called the drive gear while the unpowered gear is called the idler gear. There are two main industrial classes of belt conveyors; Those in general material handling such as those moving boxes along inside a factory and bulk material handling such as those used to transport large volumes of resources and agricultural materials, such as grain, salt, coal, ore, sand, overburden and more.

This conveyor consists of aluminum and plastic layer connected to a chain with bolts and nutsand it is considered as belt, some sprockets to transfer the power supplied by the motor to the chain by rotating it, some bearings to direct the chain and these are installed on an oval-shaped table.

2.2.2 Robotic Arm:

An industrial robotic arm is an automatic programmable robot that can perform tasks like welding, assembly and pick up and testing. They are very accurate and efficient in their tasks which reduce costs for any labor work. The first programmable robot was invented by George Devol in 1954 which was not using computers for programming but some kind of tapes with dots. The development was carried on until 2003 which led to Arc welding and handling robots.

The construction of the robot arm for our conveyor is in progress as the other capstone team project of mechatronic student [5].

2.2.3 Storage:

Safe and efficient storage of materials is a necessary in any industry. Therefore during the history of this component the inventors were trying to create a storage system that is easy to access and will not take too much space. The storage systems in the beginning were some simple wooden boxes but as the time passes they were developed into metal shelves which lead to creation of cabinet and drawers later. From 1950 until 2000 the focus shifted toward the utilization of air space this means that the rack were becoming taller and larger. The attitude of these new storage systems might reach to 16 feet. Today these shelves are not only used in the warehouses but also everywhere in the markets and even in ours houses since they allows you to access the products easily and it creates an efficient atmosphere of the environment, the usage of them is becoming more favorably inclined[6]. A sample of first storage systems can be seen in Figures 2.2 and 2.3.

Figure 2-2First storage system[7]

Figure 2-3 Storage systems in an industry warehouse in 1988.[8]

Automated storage and retrieval systems or AS/RS consists of a variety of computer-controlled systems for automatically placing and retrieving loads from defined storage locations. These automated storage and mechanized systems eliminate human need in performing basic sets of operations that includes:

- Removal of an item from a storage location automatically
- Transferring the above item to a specific processing
- After receiving an item from a processing , it is automatically stored at a known location

2.2.4 Automated Guided Vehicles (AGV):

Automated Guided Vehicles (AGV)have been around since 1953. An innovator with a vision contrived a technique for computerizing the man driven tow truck that had been utilized as a part of manufacturing plants for a considerable length of time.

He created a "track" for the vehicles to follow by imbedding a wire in the processing plant floor. The earliest guidance systems were made when sensors on the base of a tow truck searched for a magnetic field. The field was made by a current going through a wire or arrangement of wires in the floor. Station codes included a group of magnets (north/south) in the floor that a vehicle would read for halting at a station [9].

Today the engineering keeps on evolving. The wire in the floor is still used for the proper application. In any case, numerous frameworks today are consistently composed without the floor wire. Vehicles are currently outfitted with advanced processors ready for communicating, guiding, and administrating the system. New vehicle arrangements have additionally multiplied. The fundamental AGV towing system still exists. But nowadays automatic systems are used for tow applications like call systems, opportunity charging, automatic loading and unloading as well as coupling and uncoupling.

Automated Guided Vehicles or AGV are used to transport material from loading to unloading stations. They are highly flexible and intelligent. They are computer controlled with onboard microprocessors. They use position feedback to stay on a correct path using sensors.

There exists an AGV and ASRS system in our CAD/CAM laboratory so they are improving it to prepare it for installation on this conveyor.

The traditional view of material handling sees material handling operations as only increasing the cost of the product. That is why material handling should be avoided and minimized as much as possible. Since material handling operations often includes a lot of labor and labor is expensive, automation was the answer to this problem. Automation is even more important for first world countries because labor is more expensive there. The modern goals in material handling system design are to create a flexible system that can be used for a variety of products and processes and to integrate the currently designed material handling system in the overall material handling plan. Figure 2.4 shows an AGV that exists in one of the EMU Mechanical department's laboratory.

Figure 2-4- Automated Guided Vehicle in CAD/CAM lab

2.3 Embedded System:

The embedded system is a computer system with assigned operations and functions within a system and it is explained as a part of a complete system. Nowadays this system is used as a control device commonly and they are mostly based on microcontrollers. These systems are beneficial in a way that they are low power consumption, small size, better operating ranges and lower cost but it's hard to program these systems.

A microcontroller is an integrated circuit bringing together the main components of a computer like processor, memories, peripherals and input/output interfaces. Microcontrollers are characterized by a higher degree of integration, lower power consumption, lower operating speed (a few megahertz to a gigahertz) and a reduced cost compared to microprocessor used in personal computers. Compared to electronic systems like microprocessors and other components, microcontrollers allow you to decrease the size, power consumption and the cost of the products. They helped to minimize the use of computing in a large number of products and processes.

Microcontrollers are frequently used in embedded systems, such as motor controllers, remotes, office equipment, household appliances, toys, mobile phones.

The first microcontroller was the Intel 4004 of 4-bit, released in 1971, followed by the Intel 8008 and other more capable ones. However, both processors require additional circuitry to implement a system of work, raising the cost of the total system.

The microcontroller chosen for the project's task is the Arduino MEGA UNO. Arduino is a small Board with a microcontroller and boundary circuitry, useful to quickly create prototypes for educational purposes. Arduino boards can become relatively quick and simple small devices like lights controllers, motor speed, light sensors, temperature and humidity and many other projects that use sensors, actuators and communication with other devices. It comes with a simple integrated development environment for programming. All software provided is free, and the schematics are distributed as free hardware.

2.3.1 Arduino

Arduino is a modern microprocessor that helps to reduce the amount of hardware and software needed to run a system. It allows programming and serial communication over USB. It can also be used as a controlling system but it is totally a new idea. The only benefit of using Arduino is not to increase the applications done but also less space and cheaper. Traditional systems use too many sensors making Arduino the much more efficient choice [10].The used Arduino can be seen below (Figure 2.5)

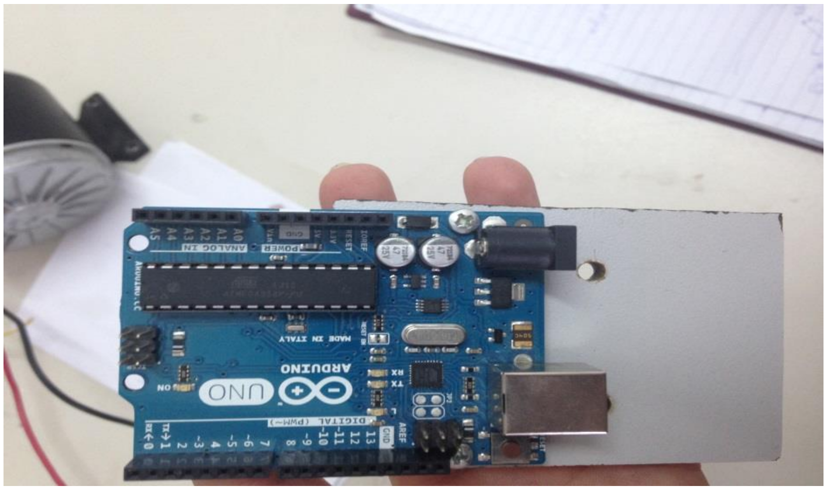


Figure 2-5- A sample of arduino used

The system also consists of an Arduino that detects moving NFC cards along the conveyer. NFC cards contain data in them from previous operations of stations along the conveyer. Every time a card passes. Arduno is also used as the robot controller. Another arduino is ued for the integration of the robot controller and the DC motor.

CHAPTER 3

DESIGN& ANALYSIS

In a flexible manufacturing system there are some stations located along the conveyor in order to stop the product and moving items on the conveyor for processing or taking away the processed items. There might either only one station installed on the conveyor or many stations depends on the processes available during a manufacturing process. Designated robots at each station automatically retrieve and replace items on and off the conveyor in order to increase the efficiency and decrease the time of the process. During this project,it was asked to design a shortcut in between the big conveyor, in which the robot is located. In the following chapters the scenario, calculations and mechanical and electrical design will be discussed.

3.1. Scenario

Figure 3.1 shows the connections between the distributed systems which is consists of the robot controller, sensors and the main controller. As it can be seen, the robot is located in the middle of the larger conveyor and as the products approach the robot station, sensor will sense them, send signal to the controller, the controller will send signal to the motor to turn on and bring the slider to the end that product is located. When the slider reaches the end it will touches limit switch which is a normal close switch used as sensor, and the switch will send signal to controller to turn off the motor and at the same time run the robot's corresponding program. Robot will bend and take the part, then sends signal to the controller, so controller will turn on the motor and the same path will be repeated on the way back to the other side.

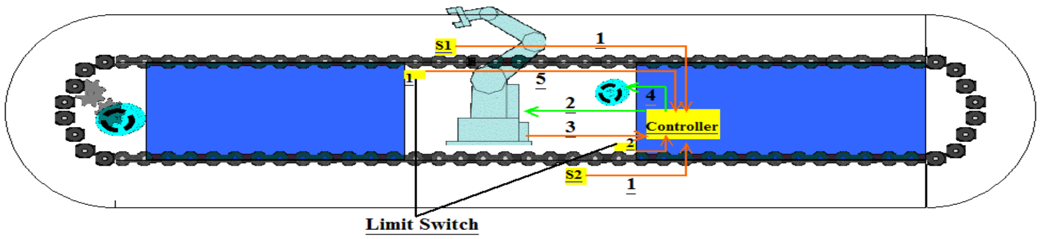


Figure 3-1- Connections

Figure 3-2- Station positions

Figure 3.2 shows the scenario of the project. As it can be seen there are 2 conveyors with a storage system, 4 stations and a junction. Raw material is coming from the storage system and they will pass from station1 and station 2, after crossing the junction and getting to the other conveyor, according to the program on their NFC card attached to them or by image processing (intelligent system), the products will go through or pass by the stations 3. In this case, the sliding robot will take the part and put it on the other side of the conveyor so there is no need for the product to pass the whole way through station 3 and then reach station 4.

During this project, two ultrasonic sensors were used on both side of the larger conveyor and near to the robot, to sense the part coming near the robotic arm and send signal to the robot to take the part and take it to the other side of the conveyor.

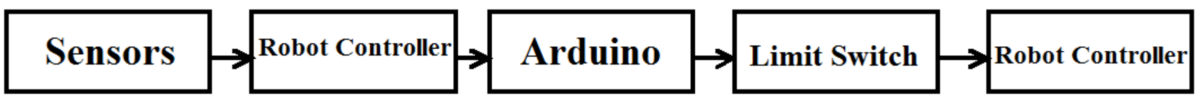


Figure 3-3- Connection between main controller and robot controller

Figure.3.3 shows the connections between the sensor, robot controller and the Arduino. When the ultrasonic sensor, which is a distance measuring sensor, senses the parts coming toward the robot, it will send signal to robot controller to run a program and grab the product. In the end of the program, robot controller will send signal to the Arduino to run the motor and direct the robot to the other side of the conveyor. There is a limit switch, normal close switch, located in the end of the sliding robot's way which will cut off the current flow in motor when the base touches it. At the same time the limit switch will send signal to robot controller and it will leave the part on the conveyor.

3.2. Calculations

In order to slide a robot on a linear path, a DC motor was used. But it was important to know whether a 12V DC motor would be sufficient to handle the weight of the robot, base and the product or not therefore some calculations were needed. In the other hand, the location of the end of the path should be specified in a way that provides a safest path for the robot to descend and grab the part or leave it on the conveyor. As it was shown in the previous section, there exist a linkage between the two conveyors an it is located near the robotic arm station, therefore the end line must be positioned in its best and safest place for the linkage and the robot. There was one more thing to take care before designing the bases and that was the measure of the mass per unit of area. In this section all these three subjects will be discussed in detail.

3.2.1 Motor Power

The electrical characteristic of the motor and its mechanical proficiency can be calculated for an ideal DC motor. A DC motor looks like a circuit with resistor and voltage back-EMF (electromotive fore). The resistor is the natural resistance of motor's coil and the back-EMF voltage is generated by the current flow in the magnetic field (because DC motor has a coil inside and when the current is conducted a magnetic field is formed). The back-EMF voltage is in relation with the motor's speed and it can also be calculated:

$$EMF = Ke * \omega \text{ (eqn.3.1)}$$

Equation one shows the back emf voltage where K_i is a constant and ω is motor speed in rad/sec.

The conducted current to the motor can be calculated as well:

$$I = \frac{(Vs - Vemf)}{R} = \frac{(Vs - (Ke * \omega))}{R} \text{ (eqn.3.2)}$$

The second equation illustrates a way of calculating the current conducted through the motor coil. Where V_s is the source voltage and R is the resistance of the motor.

The formulas mentioned earlier explain to the electrical part of the motor. The mechanical side of the motor is related to the torque produced by the motor which can also be calculated as shown in equation 3.3:

$$\tau = Kt * I \text{ (eqn.3.3)}$$

Where k_t is a constant τ is the torque produced. The mechanical power and the electrical power can also be calculated as written bellow in equations 3.4 and 3.5.

$$\text{Electrical Power:} \qquad P_e = Vs * I \text{ (eqn.3.4)}$$

Mechanical Power: $P_m = \tau * \omega$ (eqn.3.5)

All these values can proportionally change in a way that if the voltage is doubled speed (without any load) and torque is doubled and the power is fourfold.

Ω= rev/sec (eqn.3.6)

Table 3-1- Measured Values

Motor speed 1	80rev/20.81sec (24.15 rad/sec)
Motor speed 2	34.66rev/10sec (21.78 rad/sec)
Avg ω	22.96 rad/sec
Voltage	12V
Resistance	31 Ω

3.2.2. Area density Calculations:

The mass per unit area is a physical quantity that measures the mass per unit of surface. It is generally demonstrated by the Greek letter σ. The standard unit of this is kilograms per meter square (kg/m^2). The formula is the following:

$$\rho = m/A \quad \text{(eqn. 3.7)}$$

Table 0-2- Available Values

Mass of robot arm	0.5kg
Mass of base	0.1kg
Total mass	0.6 kg
Area of base	144 cm^2

3.3 Mechanical Design

Since the aim of the project was to slide a robot in between two sides of the conveyor, the primary design was using two rods to keep the robot base balanced and a threaded rod that would guide the robot to each sides of the conveyor. Due to high power needed to rotate threaded rod, that design was rejected. The second and final design was to use tooth belt, gears and rollers to move the base. 4 gears were used to transform the rotational movement of the motor into translational movement for the slider.

3.3.1 Material selection

The base is made of compact plastic because it is as light as wood, it will not face corrosion after some time and also it can handle the mass of the robotic arm. The main characteristics of this material are that it has high resistance to weathering, it can be installed and built up easily and it has low flammability. It is also easy to drill or cut this material which makes it suitable for this aim.

In order to install the ultrasonic sensor in its proper position, a nonmetallic material was used to secure it and then connect it to the aluminum stand that was screwed to the conveyor table. For this purpose, Styrofoam material was used. Styrofoam is a lightweight material that has the required strength to hold the sensor.

3.4 Electrical design

The project is not limited to the mechanical design since sensors and motors are used, a circuit design is required. To achieve this aim, a controller is used to control the signals coming from the sensors and robots and decide according to the program given to it. Arduino is the controller used to receive data coming from the sensors or robot and send signal to the motor if required.

3.5 Manufacturing Processes

Cutting tools from the workshop were used to cut the material needed for the base. Drills were used to make the holes to attach the base with screws and nuts. Turning machine was also used to make the threaded rod for the primary design.

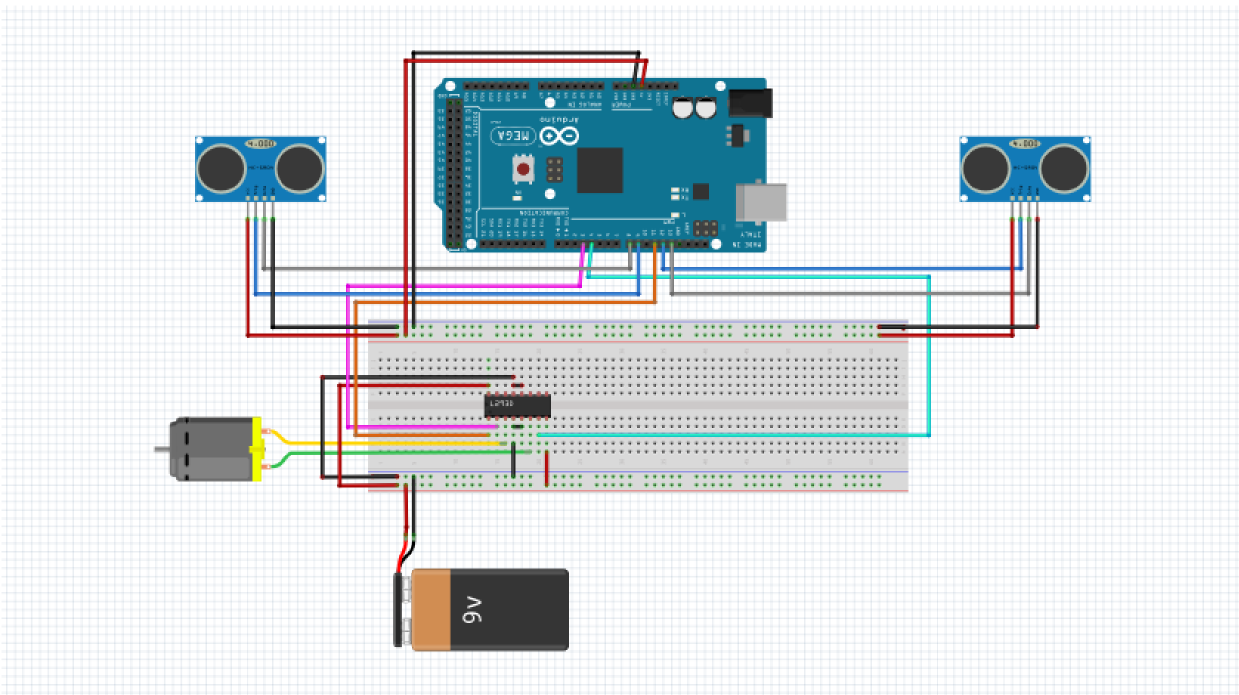


Figure 3-4- Circuit Design

Figure 3.4 shows the circuit that was used to achieve the aim. The two ultrasonic sensors are connected directly to the Arduino. The grey and blue wires show this connection. To turn on a 12 volt motor, we need a power supply, else than Arduino since it only provides 5 volts which is not sufficient to turn on a 12 volt motor. Therefore that battery is just to show that the circuit is using power supply and it is 12 volt and not 9v. It is not a proper idea to connect the DC motor directly to a microcontroller due to back EMF, therefore a relay, diode or motor driver might be used to secure the circuit and run the motor. This is the reason that the L293D motor driver is used as shown in the figure and in the middle of the bread board. Pin 1 of the motor driver which is enable pin is connected by the orange wire to digital pin 11 of the Arduino. Pin 2 and pin 7 are the input of the motor driver that is connected to digital pin 3 and 4 by pink and green wires. Pins4, 5, 12 and 13 are connected to ground by black wires. Pins 8 and 16 are connected to the positive pole of the power supply by re wires. The pin diagram of the IC is shown in Figure 3.5.

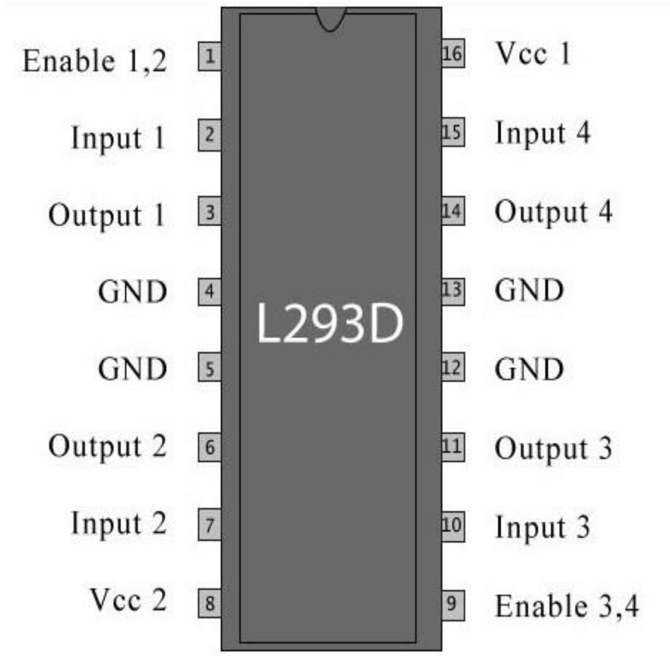


Figure 3-5- Pin Diagram of L293D motor driver [11]

3.5 Cost Analysis:

Table 3-3- Cost Analysis

Item Name	Total price ($)
Ultrasonic sensor x2	6
Raspberry Pi	50
Limit swtich x2	2
SD Memory card	6.5
Arduino Uno	25.91
Arduino Mega	48.5
Arduino ADK	45.95
Screws & nuts	20
Relays x10	16
Total	220.86

Table 3.3 shows the cost of components bought. Most of them are either bought online or from abroad because it is not available here. All of the electronic components except the sensors were coming from electrical department of EMU.

CHAPTER 4

MANUFACTURING AND ASSEMBLY

This project contains some manufacturing processes as well as the mechanical and electrical assembly. In this section, the manufacturing and the assembly ways of the design are discussed.

4.1 Manufacturing

The initial design that was using 3 rods were manufactured by lathe machine in workshop but right after that was found out it's not the suitable design for this purpose, design was replaced by the same mechanism as the printer. In the final design, there exist a body that is holding motor, gear and the tooth belt. There is also a plastic stand that is connected to the body by screws and moving by the rollers carrying bases. There are a thin and a thick base that are screwed on the stand that the robot is going to be installed on those bases. The thick base was used to pull up the base. Both thin and thick compact plastic bases were manufactured (cut) on the table saw. Figure 4.1 shows the base made from compact plastic.

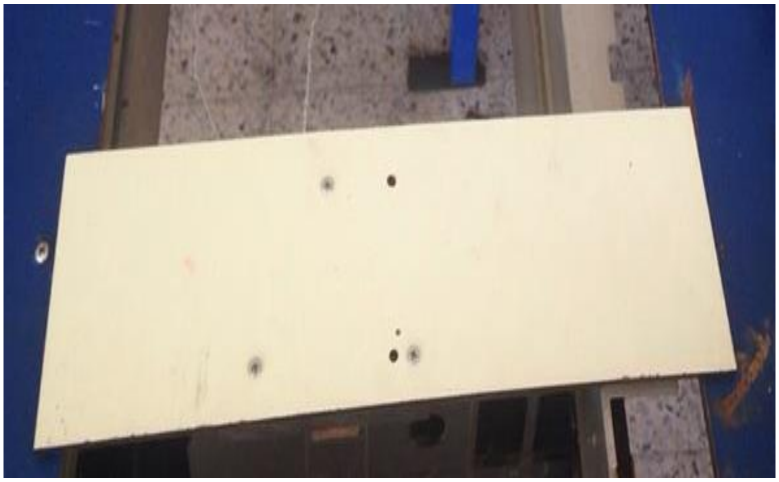


Figure 4-1 Compact plastic base

The electronic circuit was connected by soldering the wires to a circuit board. This ensures the reliable connections between the Arduino controller and all the sensors and the motor. The components were soldered in a way that, all the components that are related to each other, parallel or series, are connected with a wire and soldered at their mutual point. Figure 4.2 shows the connections after soldering.

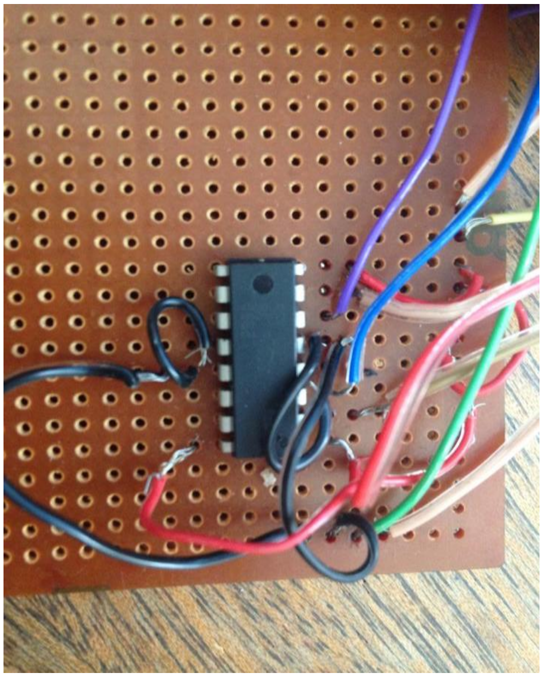


Figure 4-2- soldered circuit with L293D motor driver in the middle

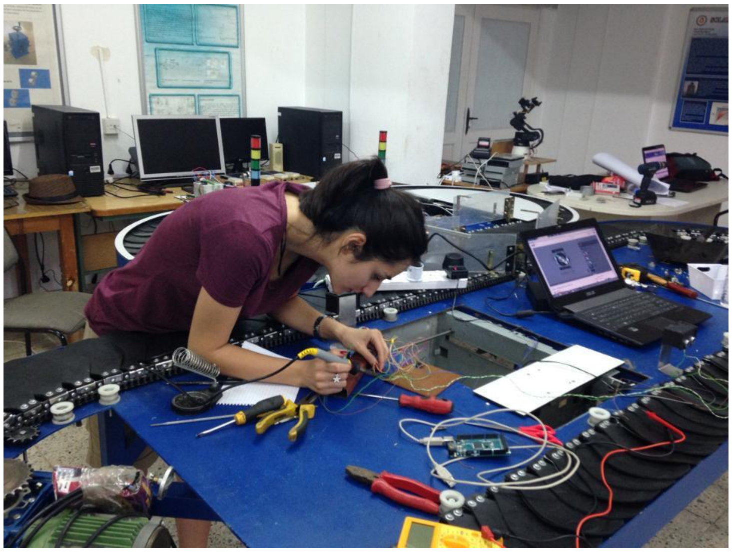


Figure 4-4Group member while soldering

Figure 4-3Group member while assembling

Figures 4.3 and 4.4 show group members while manufacturing the components or assembling the part in mechanical workshop and laboratories.

4.2 Assembly

The body, stand and the bases were all screwed together on top of the plastic base which is connected to the rollers mechanism. The standard screws, washers, nut and the bearing are shown in the appendix.The housing of the ultrasonic sensors is attached with super glue and the housing was attached on the conveyer with screw and nut. The limit switches on either end were attached to the metal frame with 2 screws and nuts each.Gears and toothed belt were used to translate the rotational movement of the motor to the linear movement of the stand. The gears were taken from an old printer. Table 4.1 shows the characteristics of the gears:

Table 4-1- Gears Used

Gear Number	Pitch Dia. (cm)	Bore	No. Of teeth	Standard		
				Style	Catalog Number	Item Code
1	4.0	0.5	64	A	QB64	09006
2	2.5	0.5	40	A	QB40	09000
3	3.0	0.5	48	A	QB48	09002
4	3.0	0.5	48	A	QB48	09002

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Motor Power Output

As it is mentioned earlier in the report the power output of the motor can be calculated. For this case that the voltage required is 12V and in the ideal case of the (without any load) motor, the average revolutions per minute is 218 which means 22.9 rad/sec. therefore the EMF constant is calculated as shown in equation 5.1:

$EMF = V/\omega$; (eqn. 5.1)

The ω value is taken from equation 3.1 in the design chapter and from the equation 5.1 comes:

$EMF = 12/23 = 0.52V$ (eqn. 5.2)

From equation 3.2 :

$I = (12-0.52) / 31 = 0.37\ \Omega$ (eqn.5.3)

$Kt = EMF$; (eqn. 5.4)

Theoretically the motor constant and the torque constant are equal but practically they have a minor difference. Therefore according to the equation 3.3, torque is equal to:

$\tau = 0.52 * 1.148 = 0.59$ N.m; (eqn. 5.5)

Mechanical Power = $P_m = 0.59 * 22.9 = 13.511$ W; (eqn. 5.6)

Electrical Power = $P_e = 12 * 1.148 = 13.778$ W; (eqn. 5.7)

On the motor, it is written that it should provide an approximate power output of 13, and the result obtained is near that value with a little error. The error is:

Error = ((13-13.778)/13.778)*100= 5.6 % (5.8)

5.2 Mass per Unit of Area

The last but not the least part is to measure the mass per unit of the area:

Mass of robot arm= 0.5kg (eqn. 5.9)

Mass of base= 0.1kg (eqn. 5.10)

Total mass= 0.6kg (eqn. 5.11)

Area of base: 144 cm^2 (eqn. 5.12)

Area Density= 0.6 kg/0.0144m2= 38.8kg/m^2 (eqn. 5.13)

5.3 Technical Difficulties

This project during design, installation and programming faced some difficulties. First problem was coming from the initial mechanical design that was using threaded rods and gears for linear movement and power transmission of the robot which required high power motor to move them due to small thread. More powerful and stronger motor means more power supply and more cost therefore it was more economical to change this design. The second difficulty faced was that, the robot controller only had 2 free pin which was not enough for this purpose, therefore another Arduino was needed which made it more complicated. The third and the last problem was due to using two Arduino for the same project, the program written was too long for this microprocessor to upload and execute it and to solve this; the program should be broken into smaller parts which made it more complicated.

CHAPTER 6

CONCLUSIONS AND FUTURE WORK

While designing a sliding base for a robotic arm one of the most important factors to consider is friction. Since a smooth movement is desired, friction should be less. By using a system with rollers and gears, the requirements have been met and friction is very low, since it only takes a 12V motor to drive the whole system. Embedded systems were used as the controlling system of the project because of its small size and low price that make advantages over big computers. Material selection was made based on the weight, size and toughness; it was also based on what was available in the labs and workshop. After this process the base was able to move to both sides successfully and stopping at the ends due to the limit switches.

As it is mentioned earlier the aim of this project is to have a distributed and intelligent system to increase the efficiency and productivity of a process by making a shortcut in between the two side of the conveyor by a sliding robot. This system is using two controllers, robot controller and main controller, and it is counted as a distributed system since these two are communicating to achieve a common goal. For the time being this robot is just pick up the products that approaches its station but later it is going to be an intelligent robot. An intelligent robot can identify the products as they are coming through the station, recognize them and decide whether to take the part or not. This can be done in three ways, first is that the robot is running a sequential program, second is using image processing and the third is RFID technology. During image processing a special camera can be mounted and image processing takes place on the monitor of a computer. This will make an intelligent system where the robotic arm can recognize what object is around and what program it needs to run in order to pick it up. The robot can also be taught about new objects that would be saved in its memory for future operations.RFID would be used in this project to detect coded magnetic cards and read the data that is stored in them. If a product which has a magnetic card identifier is on the conveyer and reaches a station, the RFID system will detect the card and would collect data that is on the card and therefore know what the product has went through and which station does it need next. If it needs the current station, processes will start on this station, if not then the product will continue going on the conveyer.

REFERENCES

1. Material Handling Equipment Retrieved: 24/12/2014, http://www.mheda.org/i4a/pages/index.cfm?pageid=478
2. . Flexible Manufacturing Systems (FMS). Retrieved: 24/12/14, http://www.uky.edu/~dsianita/611/fms.html
3. Transport of Bulk Materials by Conveyor Dates Back to 1795, Retrieved: 26/12/2014 http://www.themhedajournal.org/content/3q04/conveyors.php
4. Transport of conveyer belts, The MEHDA Journal, Retrieved: 15/06/2015 http://www.themhedajournal.org/2004/07/15/transport-of-bulk-materials-by-conveyor-dates-back-to-1795/
5. History of Industrial Robots, Retrieved: 13/12/14, http://www.robots.com/education/industrial-history
6. Storage Handling, The MEHDA Journal, Retrieved: 26/12/2014 http://www.themhedajournal.org/content/3q04/storagehandling.php
7. Storage and Handling, Retrieved: 15/06/2015 http://www.themhedajournal.org/2004/07/15/space-utilization-requirements-propel-new-design-and-technologies/
8. History of AGV, Retrieved: 28/12/2014, http://www.agvsystems.com/history-agvs/
9. "Official slogan".arduino.cc- Arduino Project. Retrieved 3/5/2015 http://en.wikipedia.org/wiki/Six_degrees_of_freedom

10. Arduino, Retrieved 10/5/2015

https://www.arduino.cc/

11. Robotix, Retrieved 18/6/2015

http://www.robotix.in/tutorials/category/auto/motor_driver

12. Global Fastener Network, Retrieved: 06/07/2015

http://www.globalfastener.com/standards/detail_2442.html,

13. Seek Part Standards, Retrieved: 06/07/2015

http://www.seekpart.com/product/UCFL207-Pillow-block-ball-bearing-ETK-standard-size-1154964.html,

14. ASME Gear Standards, Retrieved: 07/07/2015,

http://www.bostongear.com/pdf/upload/lit/P-1482-BG_pg005-050.pdf

APPENDICES

APPENDIX A

Log Book:

Date	Student	Work Performed
31/ 3/2015	Farnaz	Starting the circuit design
	Tamim	Starting the mechanical design
14/4/2015	Farnaz	Working on circuit
	Tamim	Changing the mechanical design
1/5/2015	Farnaz	Starting using arduino as controller and changing the circuit design
	Tamim	Installing the components
7/5/2015	Farnaz	Finished the circuit design and start programming
	Tamim	Working on sensor installation
18/5/2015	Farnaz	Working on programming
	Tamim	Finished with design and installation
10/6/2015		Testing

APPENDIX B

GANTT chart –Capstone Design Project II – MENG411

Spring Semester 2014-2015

Task	Feruary	March	April	May	June
Buying required compononents					
Research					
Circuit Design					
Mechanical Design					
Programming					
Installation					
Report Writing					

APPENDIX C

Drawings

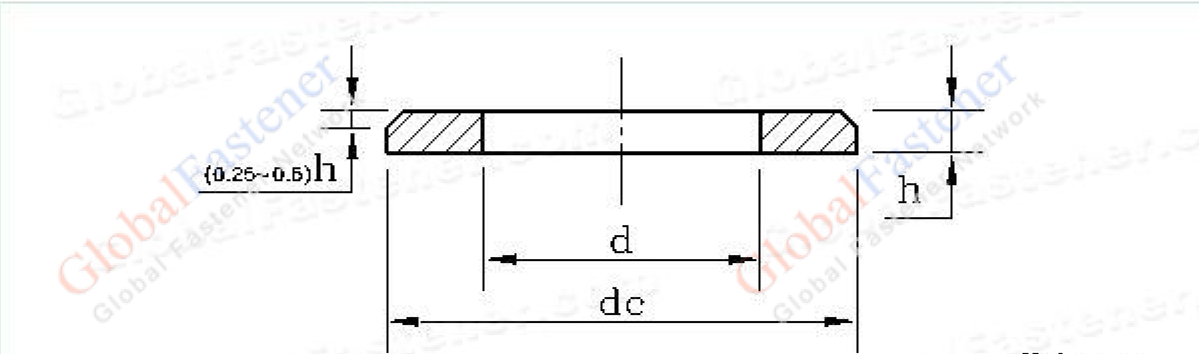
APPENDIX D
Used components

Component	Standard
Screw	M4 x 1
Nut	M4 x 1
Washer	M20
Bearing	UCT204

APPENDIX E

WASHER STANDARDS TABLE

Black washers- normal diameter, metric series (Form E), British Standard 4320 [12]



Unit: mm

Nominal thread diameter	d		dc		h		
	min=nom	max	max=nom	min	nom	max	min
M5	5.3	5.48	10	9.64	1	1.1	0.9
M6	6.4	6.62	12	11.57	1.6	1.8	1.4
M8	8.4	8.62	16	15.57	1.6	1.8	1.4
M10	10.5	10.77	20	19.48	2	2.2	1.8
M12	13	13.27	24	23.48	2.5	2.7	2.3
M14	15	15.27	28	27.48	2.5	2.7	2.3
M16	17	17.27	30	29.48	3	3.3	2.7
M18	19	19.33	34	33.38	3	3.3	2.7
M20	21	21.33	37	36.38	3	3.3	2.7
M22	23	23.33	39	38.38	3	3.3	2.7
M24	25	25.33	44	43.38	4	4.3	3.7
M27	28	28.33	50	49.38	4	4.3	3.7
M30	31	31.39	56	55.26	4	4.3	3.7
M33	34	34.62	60	58.8	5	5.6	4.4
M36	37	37.62	66	64.8	5	5.6	4.4
M39	42	42.62	72	70.8	6	6.6	5.4
M42	45	45.62	78	76.8	8	9	7
M45	48	48.62	85	83.6	8	9	7
M48	52	52.74	92	90.6	8	9	7
M52	56	56.74	98	96.6	8	9	7
M56	62	62.74	105	103.6	10	11	9
M60	66	66.74	110	108.6	10	11	9
M64	70	70.74	115	113.6	10	11	9

APPENDIX F

BEARING STANDARDS TABLE

UCT201- UCT217 Chinese Standard [13]

Unit No.	Dimensions mm in.																	Bearing No.	Housing No.	Weight (kg)
	d	o	g	p	g	S	b	k	e	a	w	j	l	h	t	B	n			
UCT201	12	16	10	51	32	19	51	12	76	89	94	32	21	61	44.5	31	12.7	UC201	T204	0.80
UCT202	15	16	10	51	32	19	51	12	76	89	94	32	21	61	44.5	31	12.7	UC202	T204	0.79
UCT203	17	16	10	51	32	19	51	12	76	89	94	32	21	61	44.5	31	12.7	UC203	T204	0.78
UCT204	20	16	10	51	32	19	51	12	76	89	94	32	21	61	44.5	31	12.7	UC204	T204	0.76
UCT205	25	16	10	51	32	19	51	12	76	89	97	32	24	62	48	34.1	14.3	UC205	T205	0.81
UCT206	30	16	10	56	37	22	57	12	89	102	113	37	28	70	53	38.1	15.9	UC206	T206	1.22
UCT207	35	16	13	64	37	22	64	12	89	102	129	37	30	78	59.5	42.9	17.5	UC207	T207	1.44
UCT208	40	19	16	83	49	29	83	16	102	114	144	49	33	89	69	49.2	19	UC208	T208	2.40
UCT209	45	19	16	83	49	29	83	16	102	117	144	49	35	87	69	49.2	19	UC209	T209	2.36
UCT210	50	19	16	83	49	29	86	16	102	117	149	49	37	90	74.5	51.6	19	UC210	T210	2.43
UCT211	55	25	19	102	64	35	95	22	130	146	171	64	38	106	76	55.6	22.2	UC211	T211	4.11
UCT212	60	32	19	102	64	35	102	22	130	146	194	64	42	119	89	65.1	25.4	UC212	T212	4.97
UCT213	65	32	21	111	70	41	121	26	151	167	224	70	44	137	89	65.1	25.4	UC213	T213	6.65
UCT214	70	32	21	111	70	41	121	26	151	167	224	70	46	137		74.6	30.2	UC214	T214	7.05
UCT215	75	32	21	111	70	41	121	26	151	167	232	70	48	140		77.8	33.3	UC215	T215	7.41
UCT216	80	32	21	111	70	41	121	26	165	184	235	70	51	140		82.6	33.3	UC216	T216	8.30
UCT217	85	38	29	124	73	48	157	30	173	198	260	73	54	162		85.7	34.1	UC217	T217	11.00

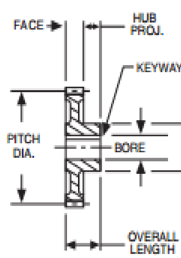
APPENDIX G

GEAR STANDARDS

ASME Spur gears standards table [14]

STEEL, NON-METALLIC AND CAST IRON

(Will not operate with 20° spurs)



STANDARD TOLERANCES

DIMENSION		TOLERANCE
BORE	All	±.0005

ALL DIMENSIONS IN INCHES
ORDER BY CATALOG NUMBER OR ITEM CODE

No. of Teeth	Pitch Dia.	Bore	Hub Dia.	Hub Proj.	Style See Page 150	Without Keyway or Setscrew Catalog Number	Without Keyway or Setscrew Item Code	With Keyway and Setscrew† Catalog Number	With Keyway and Setscrew† Item Code
16 DIAMETRAL PITCH						**Face = .500" Outside Dia. = Pitch Dia. + .125" Overall Length = .500" + Hub Proj.**			
STEEL									
32	2.000	.500	1.70	.50	A	NB32	09730	NB32-1/2	46055
		.625				–	–	NB32-5/8	46056
		.750				–	–	NB32-3/4	46057
		.875				–	–	NB32-7/8	46058
		1.000				–	–	NB32-1	46059
36	2.250	.500	1.95	.50		NB36	09732	–	–
40	2.500		1.69			NB40A	10244	–	–
48	3.000		2.19			NB48A	10246	–	–
NON-METALLIC									
16	1.000	.375	.81	.50	A	QBH16	09014	–	–
20	1.250		1.06			QBH20	09018	–	–
24	1.500	.500	1.31	.50		QBH24	09022	–	–
32	2.000		1.81	.50		QBH32	09024	–	–
40	2.500		–	–		QB40	09000	–	–
48	3.000		–	–		QB48	09002	–	–
64	4.000		–	–		QB64	09006	–	–
CAST IRON									
54	3.375	.500	1.25	.50	B	NB54	10248	–	–
56	3.500		1.25	.50		NB56	10250	–	–
60	3.750		1.38	.62		NB60	10252	–	–
64	4.000	.625	1.38	.62	C	NB64	10254	–	–
72	4.500		1.38			NB72	10256	–	–
80	5.000		1.50			NB80	10258	–	–
84	5.250		1.50			NB84	10260	–	–
96	6.000		1.50		D	NB96	10262	–	–
112	7.000		1.50			NB112	10264	–	–
120	7.500		1.50			NB120	10266	–	–
128	8.000		1.50			NB128	10268	–	–
144	9.000	.625	1.75	.75		NB144	10270	–	–
160	10.000		1.75			NB160B	10272	–	–
192	12.000		2.00			NB192B	10274	–	–

APPENDIX H
PROGRAM CODE

```
#include "DEVICES.h"

//Sensor Pins
#define TRIG_PIN1 5
#define ECHO_PIN1 6
#define TRIG_PIN2 10
#define ECHO_PIN2 11
//Motor Pins
#define MOTOR_1  7
#define MOTOR_2  8
#define MOTOR_SETUP 13

//stop the platform indicator
#define MOTOR_STOP_1 3
#define MOTOR_STOP_2 4

boolean
checkStop(int pin){
return (readVal(pin)==1);
 }

intreadVal(int p){
returndigitalRead(p);
}

SENSOR  sensor1 (TRIG_PIN1, ECHO_PIN1);
SENSOR  sensor2 (TRIG_PIN2,ECHO_PIN2);
  MOTOR   motor   (MOTOR_1,MOTOR_2,MOTOR_SETUP);

void
setup()
    {
sensor1.initialize();
sensor2.initialize();
motor.initialize();

Serial.begin (9600);
Serial.println("Sensor 1                    Sensor 2      ");

    }


void
loop()
    {
if (sensor1.detectObject()){
```

```
Serial.println("SENSOR 1");
while (!checkStop(MOTOR_STOP_1)){
motor.comeBack();
Serial.println("COME BACK");
delay(200);
        }
      }
if (sensor2.detectObject()){
Serial.println("SENSOR 2");
while(!checkStop(MOTOR_STOP_2)){
motor.go();
Serial.println("GO");
delay(200);
       }
      }
if(!sensor1.detectObject() && !sensor2.detectObject()){
motor.Stop();
      }
   /*  if (sensor1.detectObject()){
motor.comeBack();
Serial.print ("1: ");
Serial.println(sensor1.measureCm());
      }
else if (sensor2.detectObject()){
motor.go();
Serial.print ("2: ");
Serial.println(sensor2.measureCm());
      }
else{
motor.comeBack();
      }
while(checkStops() && !sensor1.detectObject() && !sensor2.detectObject()){
motor.Stop();
delay(100);
      }*/
    }
```

APPENDIX I

POSTER, WEBSITE AND CD

SLIDING ROBOTIC ARM

SUPERVISOR: DR. MAJID HASHEMIPOUR

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ABSTRACT

Robotic arms have proved to be very advantageous in industry. They are an important part in Material Handling Systems. They replace humans in repetitive and boring tasks that require constant focus and precision. . A robotic arm behaves very similar to a human arm, made of links and joints. It is clear that the future of robotics is bright, since nowadays every manufacturing plant has industrial robotic arms. Usually robot arms deal with picking and placing work pieces on and off conveyer belts. The aim of this project is to enable a robotic arm to slide between a conveyer belt, creating a shortcut and thus reducing waiting time between stations.

PROJECT AIM

The aim of this project is to create a sliding base for a robot arm, to reduce the processing time, which will be mounted on a platform in the middle of the conveyer allowing the robot arm to move linearly across the conveyer. A motor will be used to translate rotational motion into linear. This will achieve a faster and more efficient operation of 'pick and place' process rather than the usual stationary robotic arm. In the normal operation of conveyer belts, a lot of different parts would be moving on them, so at some point a certain part might encounter a busy workstation. Normally the part would 'wait' until the workstation is empty so it can pass through, but the objective of this project is to make a shortcut for this part across the conveyer to the other side.

CONCLUSION

While designing a sliding base for a robotic arm one of the most important factors to consider is friction. Since a smooth movement is desired, friction should be minimum. By using a system with rollers and gears, the requirements have been met and friction is very low, since it only takes a 12V motor to drive the whole system. The Programming part was also a necessary factor since Arduino was used along with sensors. Material selection was made based on the weight, size and toughness; it was also based on what was available in the labs and workshop. After this process the base was able to move to both sides successfully and stopping at the ends due to the limit switches. The delay in the program achieved the timing needed for the robotic arm to pick up or drop down the part.

sliderobotemu.weebly.com