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Design and fabrication of intelligent material handling system in modern manufacturing with industry 4.0 approaches

Abstract

The influence of global economy has led to changes in the conventional approaches for manufacturing companies. In this case, manufacturing companies has taken under consideration several essential characteristics such as real-time reaction to changes, quick and quality response in satisfying customer requests, in both hardware equipment and software modules by which the production processes are improved for next generation manufacturing system. Nowadays, material handling system for manufacturing purposes is the key component for any modern manufacturing processes. Additionally, due to high variety of products and shorter response times in today's manufacturing industry, the demand for smart material handling system has increased. Therefore, to recover these demands, custom-built systems should be implemented which requires individually created control software which deals with flow control, product routings, and layout and products distribution. Therefore, this paper aims to design and fabricate smart material handling system. This system includes conveyors, robot and sensors. Conveyors are designed in such a way that it can facilitate easy and has a safe loading and unloading which is done with a robotic arm. To make the system smart, it is integrated with sensors in order to be able to distinguish and distribute objects.

Keywords: intelligent material handling system, smart manufacturing, modern manufacturing, industry 4.0, conveyor

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Introduction

Overview

There have been huge changes in modern manufacturing industries. The focal point in recent advances is to increase the demand by identifying and tracking objects using real-time information.[1] Nowadays, there have been industrial revolutions in dynamic industry. Products, markets, technologies and regulatory requirement have to be adapted in modern assembly systems.[2] This has led manufactures to be more innovative to attract the global market by their conventional manufacturing methods which requires new manufacturing operations and effective factory management. Recent advanced manufacturers have been working on creating a great demand in modern industrial engineering systems regarding producing, transporting, tracking and identifying materials.[3] Modern automation and concepts are used to recover high number of product variants, smaller lot sizes, reduced time to market and shorter lifecycles of products. Therefore, modern material handling system has been the main focus among manufacturers in recent decades because it is very critical component of today's manufacturing processes.[4] There has been a vast change in material handling system (MHS) design. Modern technology has added a wide range of features in manufacturing material handling systems to compete in global markets. This has led to a rapid development in production automation, process, control, information technologies and networking.[5] Thus, manufactures have been seeking to develop an intelligent material handling system in manufacturing processes in which adding product variants and scaling production are enabled which led to high accuracy and adaptability.[6] In modern technology, an intelligent material handling system is constructed in a way that products, work stations and system are emerged by improving the communication between units in the system to create more adaptable control of assembly flow and system performance. These communication are promoted by the aid of autonomy.[7] Therefore, agent based material handling system is mostly used in recent decades due its efficiency to handle material. In real- world manufacturing systems, agent system theories have been used to combine and develop the schedule of processing operations with total processing time of the tasks released by material handling system. Julie et al. have been developed the algorithms for agent based material handling system by allocating and executing processes for all machines within the system.[8] The basic concept of agent based is the allocation process by considering the information that matches with all system entities.[9] All entities structure of software have different types of internal evaluations.[10] Thus, allocation decisions which corresponds to the specific function are made based on these embedded entities structure by the aid of the agent-based architecture[11]. However, the functionality of material handling entities in agent- based architecture is shown in Figure 1. In Figure 1, there are three fundamental level which are Constructs system level schedule, System decision making units and change existing schedules. Constructs system level schedule is responsible for global view agent while System decision making units are responsible for order agents. Furthermore, level three at the bottom is responsible for material handling agents. These three levels are integrated precisely with system monitoring and database. Global view agent is the head of this process. Its task is to communicate only with order agents. Then, order agents communicate with material handling agents. Material handling systems are very significant in many environmental aspects due to its functionality in manufacturing process. Assembling material handling system is essential for many different industries. Statics show that automotive systems in manufacturing processes can recover vast costs to the companies.[13] This briefly can be achieved by improving the combination of assembly technology and system. Designing modern material handling systems for manufacturing purposes is nowadays becoming more complex due to the growth of automation level used in industry. Robotic, electronic, and computer technologies have been developed in different areas in terms of functionality, ease of use, integration with other devices, and affordability.[14]

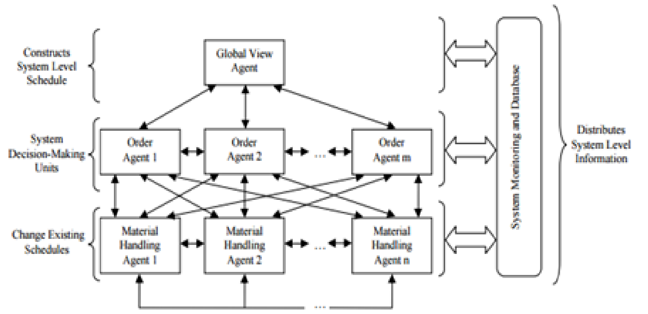

Figure 1 Agent based material Handling System Architecture.[12]

Thus, assembling an effective material handling system is not an easy task. All the upstream process of design, engineering, manufacturing, and logistics are brought together in modern manufacturing process. The main concern in assembling these kinds of systems is how an increased product varieties are managed properly.[15] This can be achieved by intelligence and collaboration between all system entities which lead to a quick respond to volatile markets and increasing product variety. Most companies are seeking to find automation and advanced manufacturing technologies for their operations in order to handle wide range of products. In other words, markets have been developed which has increased the demands on for large variety of equipment and final product assemblies. Consequently, manufacturers have paid a very close attention to this growth demand to monitor manufacturing requirement in which materials need to be well accelerated and managed. Zhang et al.,[16] worked the method to control wide range of products. In their research, a variant- oriented manufacturing system was developed to be more applicable to meet the demands in modern manufacturing systems. Modern material handling systems are assembled by focusing on different areas such as product customization, personalization, production volume, manufacturing lead time and product cost and quality. Consequently, logical entities such as controls, programs, communication protocols and human resources with a combination of tools, machines, computers, human workers have to be taken under consideration while designing and assembling any modern automotive manufacturing systems. Old material handling systems do not have the ability to handle higher-level capabilities such as accuracy, plug and play extensibility, interoperability and openness.[17] Control of material handling system adaptability is essential for assembly tasks by which dynamical reconfigurable processes are optimized for wide range of operating conditions such as loop control concept. Loop control concept play significant role in supervision, coordination and planning, situation awareness, diagnostics, and optimization.[18] Huge changes to material handling system industry is being experiencing with a fast improvement of production automation, process control, information technologies and networking. Manufactures are focusing on managing the proliferation of product variety and changes in their manufacturing systems in order to remain profitable and competitive.[19] Material handling systems are designed to meet the dynamic requirements of customers by which more advanced assembly methods and strategies are implemented.

However, Material handling system is being widely used for different manufacturing and distribution processes. Material handling purpose is to give dynamism to static elements such as materials, products, equipment, layout and human resources which make the production flow possible.[20] Conveyors, vehicles and robots are almost used in many materials handling system to transport material from one place to another. Indeed, majority of material handling systems use conveyors to transport materials from due to its high performance in the field of handling materials. For the last decades, Conveyors have been a significant tool in manufacturing and distributing systems to handle different types of products. A unique characteristic of conveyors is to sort variety types of product in the manufacturing lines.[13]

In modern industry, robots are being widely used in material handling system to increase the productivity. This depends highly on configuring or re-programming the robot manipulator to achieve the required tasks of robot.[14] In recent advances, there are series of ergonomic assist devices which are called “intelligent assist system “or “intelligent assist devices” or “collaborative robots“,[6] “holonomic manipulators”.[8] In this type of devices, a computer is used to improve the movement of heavy items in order to respond very precisely to the material handling system operations.[9] These devices work by combining human flexibility, intelligence and skills by which robotic systems capabilities are promoted. The function of collaborative robots are to share the workspace with human co-worker and assistance which integrates feedback with programming and motion guidance in semi-autonomous functions.[4] A material handling system is used for Management and production of customized products. To achieve this properly, the system must be high accurate and responsive which lead to matching between dynamic and real-time changes in material handling tasks.[3] The management of material handling system is the basic concept of improving companies’ performance. By achieving good management, transient time, resources usage and service levels.[1] Most of material handling system uses conveyors to transport materials from one place to another. They are many types of conveyors however the most popular one and efficient is known to be the belt conveyor. Belt conveyors has some stunning features which are; high reliability of operation, easy to maintain, simple design, high load carrying capacity and large of conveying path.[21] Therefore, in this paper it is going to deal with conveyors to transport the materials due to is efficiency and reliability. In addition to that a robot is going to be used to distribute different objects. Therefore, by having two different types of material handling equipment’s in the system. It will make it more productive and efficient.

Problem statement

In modern industry, the transportations of goods are significant in the integrated logistics management of semi-finished products and components flow. Manufacturing companies have been focusing on maximizing the production resources in a way that number of transport resources is minimized as well as the process optimized in terms of both production costs and time. Therefore, the prime focus on any material handling system is to optimize specific means of transport and correct organization of material flow to maintain the assure continuity of production and to deliver products to the customer just in time. Material handling system has been widely used around the world due to its functionality to reduce human interference in material processing. Manufacturing processes always requires smart material handling systems to increase the productivity in manufacturing lines. Indeed, smart material handling systems increases the production and reduces the expenses of companies. This is the reason why most companies are seeking to find very smart automated systems. The demand for material handling systems has increased due to enterprises growth in modern manufacturing process. Many companies must meet customer's demand which requires increasing the productivity scales. In this case, increasing productivity scales requires a fully smart automated material handling systems. This kind of systems has been looking for by small and medium enterprises.

Objectives

The aim of this paper to design and fabricate a smart material handling system. This can be accomplished by first by having an auto cad design of the system. This design should include position of conveyors, path of the object, position of sensors, position motors and the position of robotic arm. After the auto cad design, three long conveyors should be utilized. One of them as the main line where objects are initially loaded. The other two conveyors are utilized for unloading lines for different type of objects after differentiation. The differentiation part is going to be done by a robot arm. The robot arm should be designed and constructed to be easily controlled. The conveyors should be integrated with sensors to make the system smart. Finally, a base is needed for the system to hold the system and make it stable.

Material handling system

Automated Material handling system in industry 4.0

The world has grown closer; new data architecture has bridged vast spaces. A global network has emerged in which people and their environment and machines can communicate continuously. This has led to a high standard of safety comfort and efficiency and has changed society in people's daily lives. Most of the work processes are coordinated by data streams.[22] The entire lifecycle of a product is shaped by automated and highly networked processes. The concept production, delivery and service are digitally guided and share all their process information. People and intelligent machines cooperate efficiently. Real and digitalized process has come together in one unit. The material handling system can communicate with each other and then assemble the goods.[23] The goods know their destination hence, they can order transport of their own. All paths and procedures are connected in term of information and technology. All services updates and repairs are now automatic and are implemented on the operations. Therefore, it is really significant to have an efficient and reliable material handling system at first so that it can be developed to be smart and automated to meet today's innovation and standardization.[24]

Principles of material handling system

Material handling solutions and industrial processes can be optimized by the following principles:[25]

a. Planning principle: the material handling plan defines the purpose of the movement of object and the simplest way in which the desired job should be done. The needs, performance objectives and functional specifications need to be defined for streamlined workflow from beginning to end.

b. Standardization principle: the standardization principle requires the material and materials handling solutions to be unvarying within the limits of achieving overall functioning objectives. All of these need to be achieved without forgoing the required flexibility during work and the final throughput of the process.

c. Work principle: with this principle, the work should be minimalistic without holding back on the productivity of the task at hand. This principle also ensures that the level of service required for operation and the material handling solutions is not affected.

d. Unit load principle: this principle requires all the units of materials to be appropriately sized and stored in a way that accomplishes inventory objectives and handling of the material when required.

e. Space utilization: this principle requires the storage space to be utilized in the optimum manner so that no faulty/negative spaces are left when handling the material. This principle also includes the proper utilization of space when it comes to the non-manual material handling solutions.

f. Environmental principles: this principle is important to consider. It studies the factor if the chosen material can handle the environment conditions such as temperature or pressure. Another important parameter is the light intensity especially when sensor is being used in the system. As a different color can be detected by the sensor.

Studies done on material handling system

In this article Johnstone et al.,[26] applied the concept behind low level control. This concept plays a huge role for preventing material collision in the system. To test the concept, it has been implemented two input lines for the system. An effective layout of material handling lines was significantly required, in order for the parts to follow the right path without facing any obstacles.[26] Moreover, to obtain the desirable differentiation in the merging point; the gaps between the objects should be maintained. However, this can be only achieved by taking into control the feed conveyor, stops of input line and output line.[27] An operator designed element routing methodology for material handling system was developed by Woo and Lau. They highlight that. Current routing strategies in principle frequently put in force static routing data depending on shortest path, minimum usage, and round-robin assessments. The review outlines a material handling system to a grid with node agents associated by single direction connections control purposes behind the arrangement of a MHS parts are shown as collaborating node specialist. To settle on directing choices they characterize the most suitable route in terms of degree of tolerance to unexpected factors and material workload balancing. The authors position its approach as distributed real-time-state and map a general characterization of directing procedures.[28] In research article by Daijie HE et al.,[28] a three-step method was introduced to determine an efficient way to accelerate speed controlled belt conveyor during transient operation. The initial acceleration was estimated taking into account all the potential risk. A simulation was carried with a finite element to calculate the acceleration operation. By calculation the authors were able to study the conveyor dynamic behavior.[28] Pang & Lodewijks[29] explained that in the instantaneous operation, the high speed of the conveyor belt speed may lead to high strain of the belt. Which is the real cause of the belt fracture? During the speed control, the risk of high band strain must be foreseen. In addition to the risk of belt strain and improper transient operation may also result in the risk of object drop from the belt and the risk of high friction.[29] Hao & Shen[30] executed a hybrid simulation to create a model for handling variety of heavy and complex products on the assembly line. Their procedures comprise of proxy technologies and separate events that assists to perform adaptive environments to simulate different configurations and real-time situations.[30]

Pierreval & Durieux[31] have proposed a study to design an automated manufacturing system that will be composed of machines working in parallel both will be sharing a material handling resource. After implementing a simulation model, they identified essential component that could improve the performance of the system.[31] Schröder et al.,[32] developed an efficient way to manufacture lithium-ion battery cells using automated material handling system.[32] They improved the continuous process flow on shaping the z-folded electrode by grasping electrodes, unwinding separator and a subsequent continuous z-folding without setting and resetting. Culler and Long proposed a prototype smart materials warehouse by which new aspects were explored. In their work, they used such as four multi-purpose mobile robots automated guided vehicle (AGV), wireless Arduino controls, and fabricated components. One of the robots has a Microsoft Kinect camera. This camera has different purposes. All this were integrated to form a smart warehouse in which shipping/receiving, storage, staging areas, and processes including cutting, milling, and turning for preparing raw stock can be performed.[32] Masood et al.,[33] investigated the methodologies and techniques to design a proper conveyor for different material handling systems.[33] In their paper, they have discussed some methods which can potentially reduce the cost of the conveyor. They proposed in one of the methods how to strengthen the side frame which is primary support in the conveyor system. Moreover, Mohsen worked on the methods of choosing the proper equipment for Flexible Material Handling System FMH using Fuzzy Analytic Hierarchy Process (FAHP).[34] There is a high competition among the designers to select material handling equipment which is a very complex task. In this case, many researchers have been working to develop how to choose the right equipment for material handling System. Chan proposed a model for improving material handling system called material handling equipment selection advisor (MHESA).[35] Bhattacharya also proposed another method which is called multi criteria decision making (MCDM) environment.[36] Lin worked on the development fuzzy TOPSIS method for robot selection.

Design of material handling system

Overview

Nowadays material handling system became the key component in many industries. However, the system can be designed in many ways depending on certain requirements. Therefore, this chapter will include the proposed and the design of the system with its suitable dimensions.

Description of the system

Referring to Figure 2 the system can be divided into 4 phases. The first phase consists of 4 sensors, storage buffer and a conveyor. Phase 2 consists of robotic arm. Phase 3 and phase 4 are similar except that they are in the opposite direction. Both phases consist of 2 sliders, 2 conveyors, unloading buffers and 2 sensors. The unloading buffer contains of different colors pockets. Each phase in the system has a different operation. For the first phase 3 sensors are used. Sensor 1 is used to initialize the conveyor. Sensor 2 is added to the system to slow down the motion of the conveyor. It is so important to have sensor 2, because without it the conveyor will move in a high speed. In high motion sensor 3 which is used to stop the motion of the conveyor won't have enough time to detect the presence of the object. In addition to that it is so important to stop the object at the same position. Since the robotic arm is programmed to pick at a specific position. Therefore, if the object is being stopped at different position, the robotic arm won't be able to pick it up. Hence it is necessary to slow down the motion by sensor 2 and eventually sensor 3 will be able to stop the object at the same place. Phase 2 consists of a robot arm. This robot arm's job is to pick the object from conveyor 1 and place it either on conveyor 2 or conveyor 3 depending on the colors. In phase 3 and phase 4, the sensors are added at the beginning of the conveyors. These sensors are used to start the motion of the conveyors. However, for these 2 phases there is no a sensor where it stops it. Since the object should slide to the slider. The main role for the conveyors is to handle materials from one place to another. The first conveyor handles material from the initial position and stops in a position where the robot can pick and place it on the second and third conveyor. Conveyor 2 and conveyor 3 start to handle materials once the robot place the object in front of the sensor. These conveyors then unload the objects smoothly to the slider.

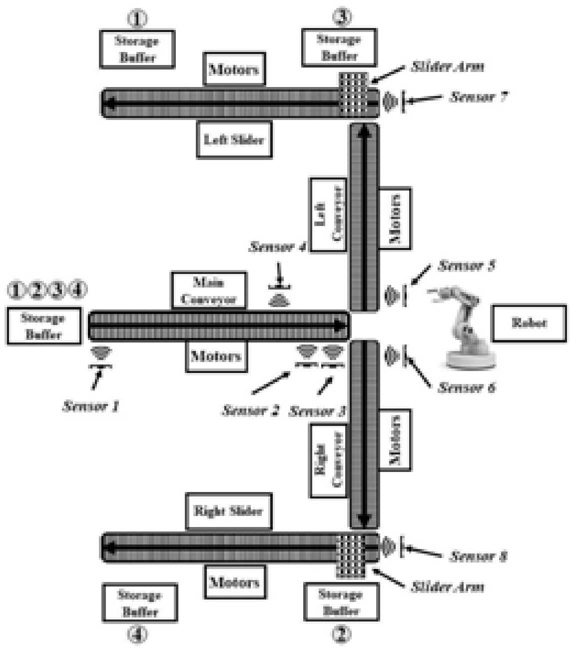

Figure 2 Schematic diagram of the whole system.

Design of the system

The system is designed using auto cad as shown in Figure 3. In this design, the dimension and spaces of the equipment have been studied. The robot arm is placed 5cm away from conveyor 1, and 8.5cm away from conveyor 2 and conveyor 3. It is so important to maintain the specified distance for the robot arm to have enough space while moving. All three conveyors are 8cm in width. The distance of this width is studied for the conveyor to handle objects of 4 cm. each conveyor on the system has 2 motor boxes. The motor box consists of 2 motors. Each box has a dimension of 14 cm by 14cm.

Design of the main conveyor

For the main conveyor, it has 4 sensors as shown in Figure 4. The first sensor should be so close to the start of the conveyor to initialize the motion. First sensor is positioned 7cm away from the start edge which is assumed to be reference point. Second sensor is positioned 60 cm away from the reference point. Consequently sensor 3 and sensor 4 are in top of each other and are placed 72cm away from the reference point. In Figure 5 the diagram shows the left view of the conveyor. From this view, it can be noticed that the height is 7.50 cm from the ground. The motors are placed 4.0cm from each end of the conveyor. The conveyor has 10gears. However, from the left view only 8gears can be seen.

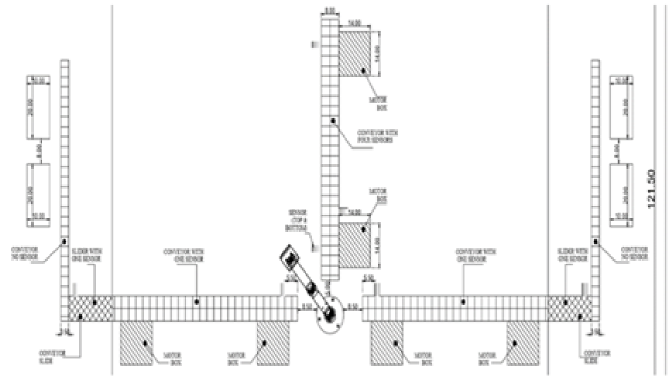

Figure 3 Top view of the system.

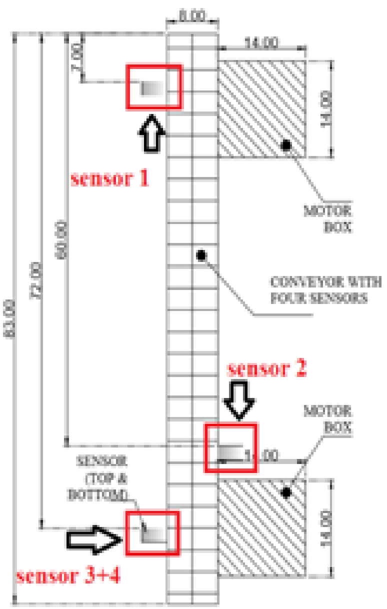

Figure 4 Top view of the main conveyor.

Design of the second and third conveyor

Conveyor 2 and conveyor 3 have the same operation therefore they have the same design. Both conveyors have one sensor as shown in Figure 6. This sensor is located 5.50cm from the edge of the conveyors.

The base of the system

After constructing all system conveyors, a table was built to fix all the conveyors on it as shown in Figure 7 the table was constructed in two levels. The first level has all differentiation system equipment which separates objects while the second level is for the distribution system to categorize objects to their locations.

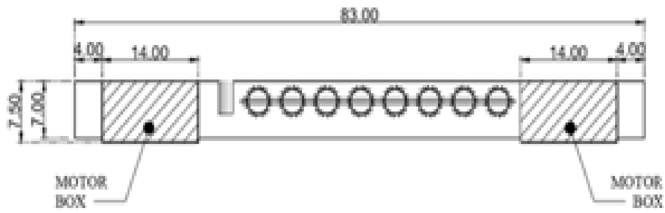

Figure 5 Top view of the second and third conveyor.

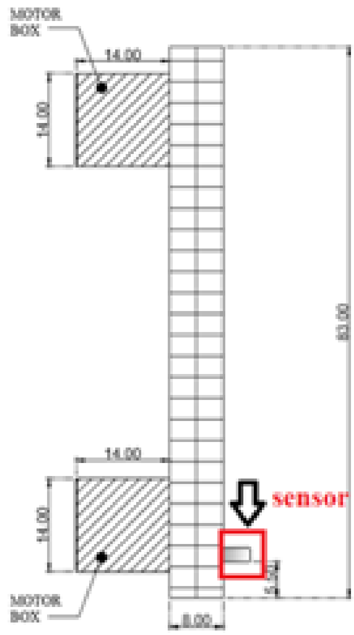

Figure 6 Left view of the conveyor.

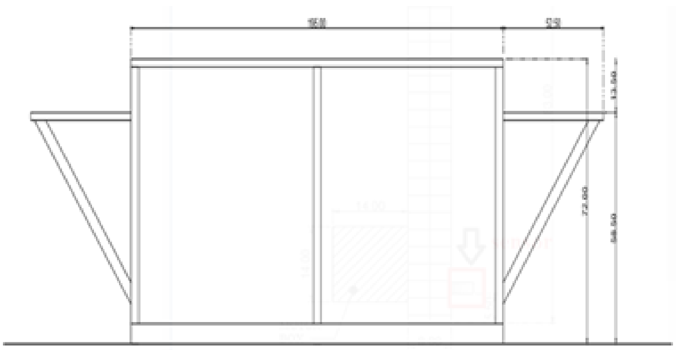

Figure 7 Side view of the base.

Fabrication of material handling system

Overview

The schematic diagram that was shown in chapter 3 is then implemented several times to have the suitable design for the material handling system. This chapter will summarize the fabrication of two of material handling equipment's which were used in the system which are conveyors and the robot arm.in addition to that it will include some of the problems faced during fabrication and its correspondence solution.

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Fabrication of the conveyor

Different designs of gear connections

There are several different ways in connecting the wheels; however below is the 2 designs which are tested

Connection of gear with yellow beams: The 2 gears are connected by a single 7cm rod which is known as an axle, and for the spacing between two wheels, 2 yellow, 3-module beams are used as shown in Figure 8.

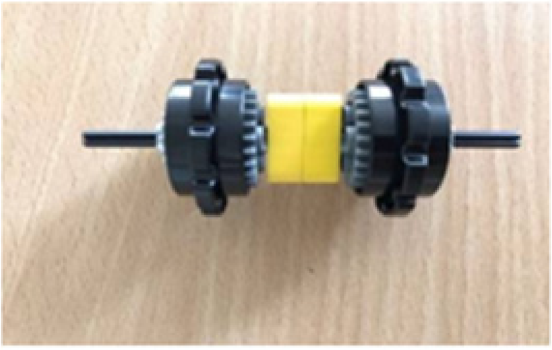

Figure 8 Gear connections A.

Connection of gears with spacers: The two gears are connected by an axle of 7cm, and for the spacing a grey worm gear is used as shown in Figure 9.

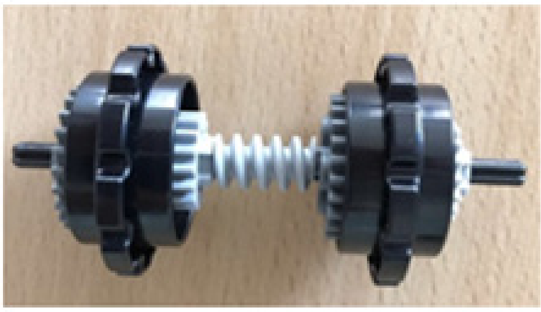

Figure 9 Gear connections B.

Suitable connection of the gears: The different designs of gear connection have been tested. By comparing the performance of both. It was noticed that the most suitable connection for the gear is the connection with the grey spacers as shown in Figure 9. Since the distance between the two belts is less and the performance was much better than the one connected with the yellow axle. On the other hand, in both connections, a common mistake was found in connecting these belts on the same level. Belts should be on the same level to decrease the vibration of the system. To overcome this issue, it had been figured out that each wheel has a dot, so these dots should match the other wheel's dots to equalize the level of belts.

Width of the conveyor belt: By using wheel connection B, the width of the two conveyor belts with 20 wheels in total is 7.5cm.

Connection of the motors: After connecting these two conveyors successfully, different motors installation was evaluated for the system. In the first implementation, one motor was used to rotate the conveyors. Unfortunately, the conveyor movement was difficult due to the insufficient power. Consequently, two motors were installed from different directions. One motor was installed in the beginning and the other one was in the end but in the opposite direction to the first one. In this case, improvement in the conveyor's movement had been realized but the vibration was more. Thereafter, two motors were put on the same side. It has been noticed that the vibration was less but the conveyor movement is not satisfied. In this case, increasing the number of motors was decided to make the conveyor's movement more powerful. For the next design, it had 4 motors positioned in series to each other; 2 in the middle and the other 2 were at the edges as shown in Figure 10. After implementation, it had been noticed that the movement had slightly improved. However, a severe problem occurred when testing the conveyor each motor was only enabling the movement of the corresponding wheel attached with the motor, the other wheels were not working and it had a lot of vibration. Eventually, 4 motors were installed on the same side but in a different way as shown in Figure 11. In this method, each two motors were connected. In this type of connection, vibration and movement of conveyor were satisfied. Figure 12 shows the most stable conveyor belt which was achieved.

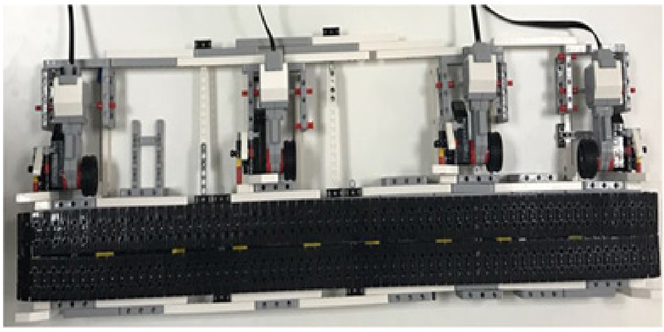

Figure 10 Motors connection A.

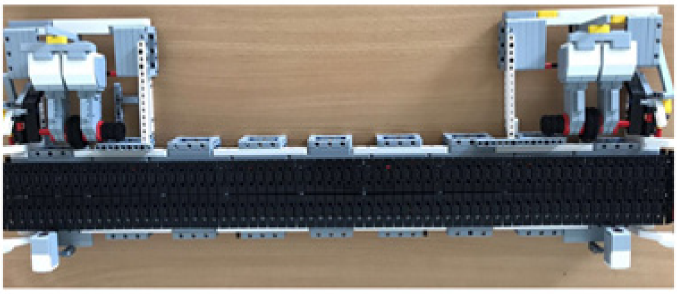

Figure 11 Motors connection B.

Problems and improvements for the system: The distance between the gear's shafts as shown in Figure 13 is significant. At the beginning, the distance between wheels was 11cm. In this case it has been noticed that not all the wheels are moving together. This resulted in high vibration. Therefore, it has been decided to reduce the distance between the wheels, so wheels will encourage easily other wheels to move. Then, the distance is reduced to 9.5cm. After that, the movement of wheels and vibration had been promoted. Furthermore, not only the distance between wheels was detected, the distance between stands was also inspected as shown in Figure 14.

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This distance was a controversial issue because it is the dominator of the vibration. When the system was constructed in the beginning, this distance was 12cm. Then it was observed that the vibration is not in the desired state. From there on, it was proposed to reduce the distance between stands by adding more stands. Therefore, the distance was decreased to 3.2cm. After applying this proposal, the desired vibration was achieved. Another factor of vibration is due to the connection between the wheels and motors. To reduce the vibration in this section, a connecting shaft was used as shown in Figure 15. This shaft works to keep two edges of the beam together. Then, to make the system more stable additional things were added such as the number of joints and linkages. Moreover, the movement of motors was making vibration to the whole system. Therefore, to reduce this source of vibration, the motors were tightened together and linked to the main construction as shown in Figure 16. In this project, the two motors were linked together. This is a new idea, which makes the rotation of motors more powerful. After accomplishing a stable conveyor belt, sensors were installed horizontally to detect different materials as shown in Figure 17. Installing sensors horizontally is more efficient than vertically. In the vertical way, sensing material will be limited to one position. In this case, materials will not be detected if they do not come in the exact place where the sensor is placed. On the other hand, by installing the sensors horizontally, materials will be detected directly when they pass in front of the sensor. The type of sensor that is being installed is the color sensor. Color sensor are used to distinguish 7 different colors and it can also detect the absence of color.it has an additional astonishing feature; which it can detect the light intensity. When the system was being tested, a problem was being detected. It has been realized that the sensor which was being used has some limitations. Due to its limitations, the object was not stopping at the same position every time. Therefore, it was decided to add a guideline to the conveyor as shown in Figure 18.

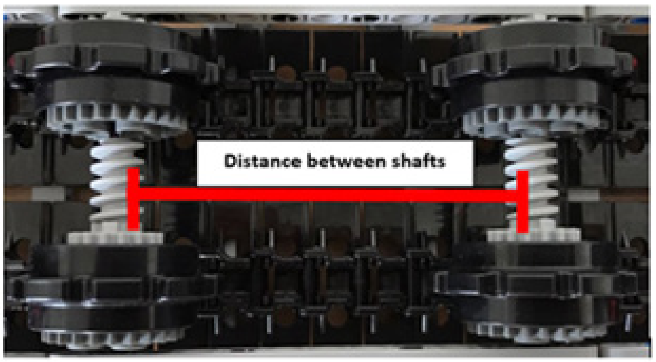

Figure 12 Distance between two gears.

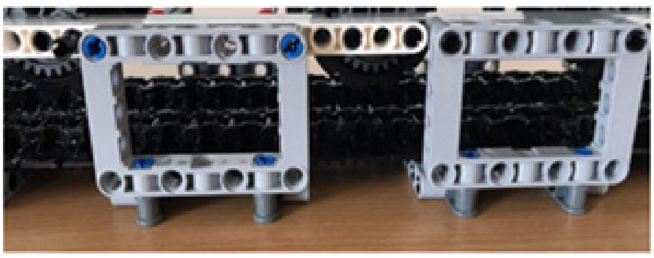

Figure 13 Stand of the conveyor.

Figure 14 Stand-beam connections.

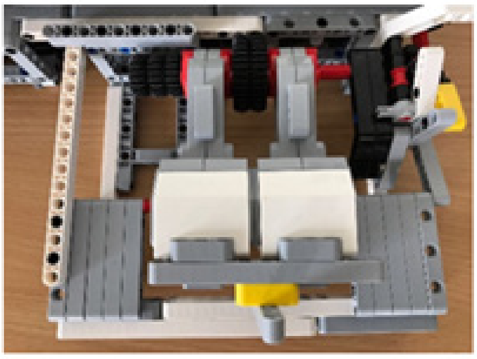

Figure 15 Motors stand.

Figure 16 Position of sensor.

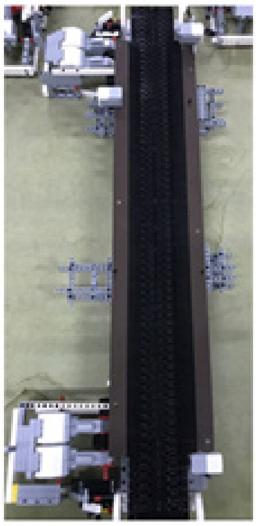

Figure 17 Main conveyor with a guide.

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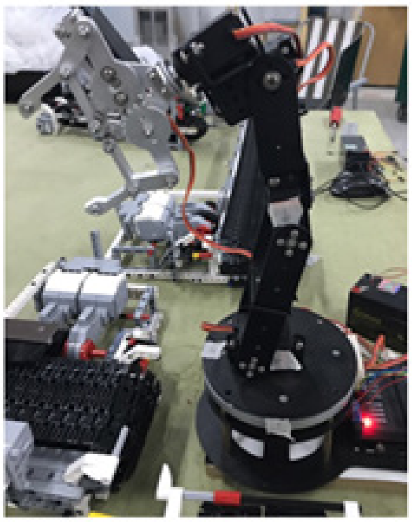

Figure 18 Robot arm.

Fabrication of the robot arm

The robot that was used in the system is shown in Figure 19. The following robot has 6 servo motors. Servo motors has different functionality than a Dc motor. These servos cannot be assigned to a power level. It should be given a position value. Then according to the specified position, it will rotate to it. These servos don't have 360 degrees of range. Therefore, this means they have limited motion. It has 256 position values with a range of 180 degree of motion as shown in Figure 19. For that specific reason before assembling each motor. It was being tested by connecting the servos to the servo controller and to a 12 v battery. This servo is then connected to the input of the robot control agent. Then it was tested in which way it can be assembled where it can give the maximum flexibility of the robot and a mark was given to the 0 position and the limit so that when it's programmed it doesn't exceed the limit.

Figure 19 Servo motor.

Results and discussion

The main key issue in designing the system was its stability. Many designs were implemented to test the performance. Consequently, many aspects have been inspected which caused a problem in functionality of the system. These aspects were mainly the connection of gears, number of gears, number of motors, positioning of the motors, and length of conveyor belt and stability of the stands. These aspects were studied and have been adjusted in a way to have the maximum efficiency of the system. This resulted in less vibration of the system and the object was easily transported from one position to another. The main focal point on the robotic arm design was the gripper. The initial design of the gripper was able only to pick up very small objects. Changing the size of the object was not a solution as some challenges occurred. The challenges were that object didn't produce equal forces on the double conveyor belts; one side had more force than the other. In this case stability of the system was decreased and the parts were tripping off and the robotic arm couldn't pick it up. The final design which was offsetting the gripper, however more spacers were needed unfortunately there was no, washers were used instead. By testing this structure, the robotic arm had better functionality and it could pick up the objects. Therefore after all problems were solved the conveyors and robot were fixed as shown in Figure 20.

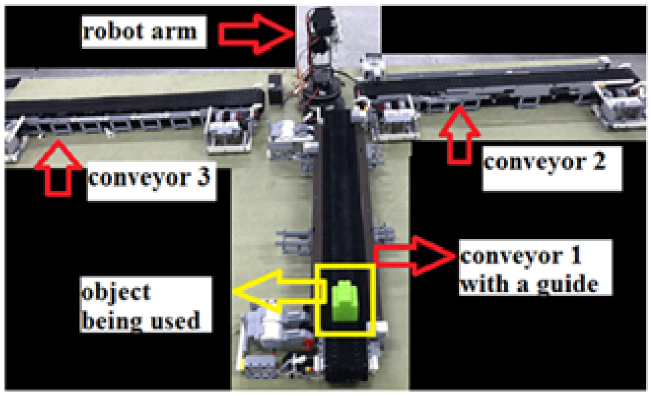

Figure 20 Material handling system.

Conclusion

The main purpose of this paper is to have an automated smart system. However, to integrate the system with the control units, a design and a model was needed. Therefore 3 conveyors were constructed in a way it has high stability, maximum efficiency and low vibration. These conveyors were used to transport the objects from one position to another. A robot arm was constructed to pick and place the objects. Therefore, after construction, the system was integrated with sensors. In integration the system with sensors, the main problem was that the sensors couldn't detect if the object was far away from the sensor. Therefore, when a guideline was fixed to guide the object in front of the sensor. A huge improvement was noticed in the system as the sensor could detect the presence of the object. A second problem noticed is when the conveyor functions in a high speed, the sensor fails to send a signal on defining the color of the object. By adding a second sensor in between to slow the motion of the system. The system has attained better results and the sensor was able to send signals and distinguish different colors. Therefore, it can be concluded that the design which was proposed for the system, was very efficient and lead to good results. The position of each equipment was suitable and it had enough freedom to function in a successful and desired way. Due to the limited availability materials for constructing the conveyors, plastic parts were used. This plastic parts by time result in plastic deformation due to load applied to it by the motors.

Therefore, it is recommended in future to change the material used for fabricating the conveyors. In addition to that to change the type of sensors used due to its limitation. Changing the sensors could lead to decrease number of sensors used in the system.

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Conflict of interest

The author declares there is no conflict of interest.

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