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# Investigation and implementation of material handling principles for an automated guided vehicle for agricultural purposes


## Abstract

With the current challenges of rising population and scarcity of natural resources, the need for new technologies becomes more important to increase efficiency in the agriculture industry. Robotics technologies alone, serve quite well for the different problems in the field of agriculture. Automatic systems and robots are used for irrigation systems and targeting to decrease the manpower defects as well as save on energy and time. Sprinkle irrigation importance lies in that it provides irrigation for the crops by imitating an actual rain fall and it contributes in reducing water consumption because Water is distributed more evenly across the farm to avoid depletion. Since, in sprinkler irrigation traditional method, irrigation sprinkle nuzzles should be placed in all the farm land or after each period of irrigation the position of the sprinklers must be replaced by manpower, this struggle makes the method inefficient from energy, cost and time points of view. In the present work, an automated guided vehicle is proposed to replace irrigation sprinkles within an integrated automated agricultural system. The proposed system has the ability to replace sprinklers timely and on appropriate positions automatically or with less manpower need. The AGV is presented to navigate independently through the row crops in a field, aided with different sensors and a robotic arm with a gripper to achieve various tasks. Optimizing AGV's size is really significant while it is used in any material handling like in Agriculture purposes. Thus, this AGV will be constructed in a way that the size would significantly promote energy consumption and it does not impact the operation field and performance, by that material handling system such as space utilizing, energy and simplification principle are developed.


**Keywords:** AGV, robot arm, line following, material handling principles

Volume 4 Issue 6 - 2018

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**Received:** May 15, 2018 | **Published:** November 01, 2018

## Introduction

### Background

One of the most important economic movements is agriculture; as it provides food and fuel for the humanity.[1] The worldwide population anticipated that it would reach more than 9 billion by 2050.[2] Agricultural production should become double to meet the expanding demand for nourishment and bio-energy, so in order to meet the growing demand for nourishment and bio-energy, the agricultural production should become double.[2] Provided the restricted land, water, and labor, it is evaluated that agricultural productivity must rise by 25% to meet that objective,[3] all that while constraining the developing pressure that farming puts on the earth. For the humanity and the earth to meet its future farming production needs, robotics and automation will play a significant role.[3]

**Roles of robots in agriculture:** For sixty years, robots have taken place a crucial part in expanding the proficiency and diminishing the cost of industrial production. Over the recent three decades, a comparable pattern has begun to occur in agriculture, with vision based and GPS independently directed tractors and gatherers, which are as of now accessible commercially.[3] More recently, farmers have begun to explore different avenues regarding systems that automatically operate tasks like pruning, thinning, and collection, on top of weed removal, and spraying. In the case of fruit industry, the workers on automated stages are as twice as efficient as workers using ladders to collect fruits. Progresses in sensors and control systems take into consideration as ideal asset and incorporated pest and disease management.[3] An unfiltered search on literatures for the query "agricultural or agriculture" and "robot or robotics" shows the increased interest from the technological community to apply sensing, mobility, manipulation, and management technologies to meet agricultural needs (Figure 1). Progressing research in robotics and automation related to agriculture concentrates on incorporating machines and portable vehicles with the technology expected to enhance human workforce and increase their profitability, or to substitute human workers in undesirable or relentless activities in fields, farms, green houses, vegetable nurseries, forests, and animal production. The graph reveals the increased interest from the robotics and automation community to apply sensing, mobility, manipulation, and management technologies to meet agricultural need.[4]

**Irrigation objectives:** Government and states of the world have been forced to increase farming products per area and optimize water and land resources to face the challenges of global population escalation and limited water resources. For the most part, current irrigation ways are divided into gravitational and pressure systems. The pressure systems usually contain drip water platforms and Gravitational systems most of the time; make use of furrow irrigation.[5] By resource management and optimizing the water consumption, it could be possible to improve the economic productivity. If compared with traditional irrigation systems, the automatic systems are anticipated to lower water consumption without compromising production rate.[6]

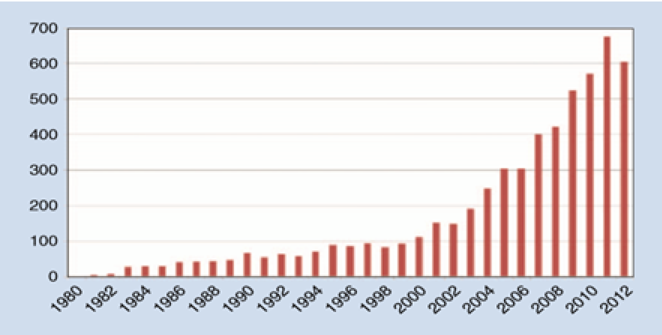


**Figure 1** Number of articles that have been published.[4]

**Automation in Agriculture:** Agriculture sector is labor intense, heavily relied on man power. Remarkably, in countries where the work force is limited, employing agricultural workers is of high cost and most of all, agricultural yield is high; there is an increasing demand pattern towards a highly automated agriculture.[7] Automation is needed not just for the whole process of growing plants but also during the transportation and storage of the agricultural goods. Elements of mechatronics are present in every application of technological automation. In agriculture, the monitoring of crops, plant and animals, harvesting and maintenance of the land and water systems are among the mechatronics activities.[8] Although automatic systems could address the issues with no constant human presence and growing season monitoring, continual closeness of human workers to run water system programmed instruments isn't economic. In the future it will be more necessary to develop the role of farmers as managers and off-field supervisors mainly with the application of modern irrigation systems, especially with the addition of new processors and controllers, as well as technological developments.[9] Efficiency is much lowered by human faults where delays and poor decision making cause serious losses. Therefore, it would be vital to increase the performance and optimize resources consumption by irrigation units. For a more efficient irrigation system and performance of water consumption, following measures are recommended:[10]

a. Software to develop scientific irrigation program to achieve practical requirements.

b. Using modern irrigation methods regarding automation level of each irrigation unit.

c. Use of AGV in irrigation

d. Invest in popularizing and teaching modern irrigation units.

e. Implementing of automatic systems to avoid human faults

In this paper, an Automatic guided vehicle is to be built and used in sprinkler irrigation system to replace sprinklers periodically and on appropriate positions. In all agricultural robots, sensors play a key role. They range in complexity from simple to complex. Thanks to agricultural crops, robot sensor systems are widely used. For instance, plant cutters have vibration analysis liquid flow, and sensitive agriculture has GPS.[11] Many studies about autonomous robot for agricultural applications can be found in scientific literature.[7,8,11] In most cases robotic platforms have be conceived to operate in open field, where autonomous guidance is rather complex owing to the absence of universal references as well as the diversity and inconsistent operative environments. For this reasons only in very rare cases prototypes have achieved a commercial stage. On the contrary, pot-plant nurseries are more suitable to the addition of autonomous robotic platform than open farms.

## Material handling system

**Importance of material handling system:** One of the fundamental mechanisms in agriculture method is its material handling systems. It refers to actions, apparatus, and processes linked to the motion, storing, protecting and controlling of materials in a system. The material handling systems include some principles in it which are essential in any application of material handling system and its had a lot of objectives in it such as:, it is efficient and safe motion of substance to the required position, timely motion of substance when required, stability of production, storing of supplies using lowest amount of space, minimum price solution to the materials handling actions, improved distribution system, saving time and better degree of safety.[12] Material handling solutions associated with productive constructing system design is able to decreases factories operating prices within 15-30%.[13] The primary step in automating material handling took place in 1950s with the achievement of Automatic Guided Vehicle Systems (AGVS). Automatic Guided Vehicle Systems are known as battery-driven manufacturing trucks with contactless navigation.[14] Efficient material handling is the most essential element of constructing and distributing procedures because without it the final creation cannot be turned into profit.[15] Even though, the straightforward price of material handling cannot be estimated, the major aspect attributing to material handling expenses are wasted time. An idle apparatus operator is basically being paid though it does not produce any value. The next major cost related with material handling is labor expenses. The transportation of the supplies is critical, however it does not straightforwardly add to the ended product. Furthermore, rising labor and workers compensation expenses make material handling substitutes also more wanted. Material handling has developed enormously from the moment it began as completely manual operations, where employees were working to lift, stack, tote, and count.[16] Workers transporting supplies utilizing motorized tools, like powered-jack or pallet truck, result in extra worthless added expenses to a product. Material handling systems are always capable to be enhanced, but infrequently eliminated. Nearly all procedures, material handling is able to account for nearly 30-75% of goods total manufacture cost.[17] In addition, in a usual manufacturing firm, material handling accounts for 25% of workers, 55% of the entire plant space, and 87% of the construction time.[18] Streamlining material handling systems is capable of significantly decreases expenses across all fields. For that reason, material handling is definitely one of the primary things to look for efficient utilization of workers and capacity space, minimizing manufacture lead times, developing efficiency of material stream, rising efficiency, and minimizing the total cost. Material handling is an obligatory factor in most manufacture and distribution systems and has adverse influence on execution of organizations.[19] Due to the quantity of activities, problems can arise in a wide range of contexts, and for example longer lead times, high amount of time spent on material handling and unnecessary movements can occur. This directly impacts on financial performance and competitiveness of the cement manufacturing firms. In addition there are numerous principles which in involves in material handling systems which are as follow:

## Material handling system principles

**Orientation principle:** It promotes study of all presented system relationships ahead of moving towards preliminary arrangement, to recognize obtainable processes and problems, physical and financial limitation, and to establish upcoming supplies and aims.[20]

**Planning principle:** It is setting up a plan that involves fundamental requirements, advantageous alternates and planning for eventuality for all material handling activities. Furthermore this plan must indicate the planned objectives of the institute and additionally the immediate needs.[21]

**Systems principle:** It incorporates handling and storage actions that are expense effective into a coordinated system of processes that includes receiving, inspection, storage, construction, building, packaging, warehousing and transportation, which is basically price effective into incorporated system design.[21]

**Space utilization principle:** Promotes efficient utilization of all the area existing by using less space as possible, for example reducing the size of an object in order to use less space or to have an alternative movement without having to consume more space for example adding wheels that are capable of moving on both X-axis and Y-axis.[22]

**Standardization principle:** Material handling processes, apparatus, controls and shareware must be standardized within the limits of accomplishing overall implementation objectives and without giving up required adaptability, modularity and throughput.[23]

**Ergonomic principle:** It identifies human being abilities and limitation by designing efficient handling tools and processes for efficient interaction with the public utilizing the system. It incorporates both physical and intellectual duties.[20]

**Energy principle:** It involves expenditure of energy throughout material handling systems and material handling processes when making comparisons or setting up profitable justifications.[24]

**Mechanization principle:** It promotes mechanization of handling procedures anywhere possible in order to encourage efficiency and financial system in the handling of materials.[22]

**Simplification principle:** It promotes simplification of systems and procedures by getting rid of and minimizing needless movements and apparatus, which could reduce the weight of the object that can make the movement much easier.[25]

**Cost principle:** It evaluates the financial justification of alternating solutions in apparatus and techniques on the foundation of financial efficiency as measured by price for each unit handled. it incorporates all income that will happen between the time the first cash is spent to arrange or obtain another new piece of equipment, or to set up new technique, until that strategy or equipment is replaced.[20]

## Problem statement

To increase the productivity of small to medium farms, an AGV for agricultural purposes is experimented and is to be built to navigate through the field guided by sensors and equipped with a robot arm to replace sprinkles. While the positions of sprinklers have to be replaced manually after each periodic irrigation, this makes the sprinkler irrigation conventional method inefficient from energy, cost and time points of view. The project aims to design and build an automatic guided vehicle which is capable of replacing irrigation sprinklers timely and on designated positions. The automatic guided vehicle is presented to navigate independently through the row crops in a field, aided with different sensors and a robotic arm with a gripper to achieve various tasks.

## Project objective

The paper aims to construct an AGV integrated with a Robotic arm to replace irrigation sprinkles in which material handling principles are taken under consideration such as space utilization, energy, and planning and simplification principle. The movement of this AGV will be achieved in a way that it does not impact the size of the field. Additionally, the motion of AGV wheels and motion of the gripper will be integrated to optimize energy consumption and cost; also unnecessary parts will be removed from the AGV so the weight could be as light as possible in order for it to move without difficulty. The structure is to be built using aluminum parts, these parts are used to construct both the chassis and the robotic arm. And Arduino shall be used to program and control the movement of the AGV and together with Arduino a servo motor controller shall be optimized to control robotic arm. The robot should be able to follow a line track for navigation and simultaneously pick and place an irrigation sprinkle nozzle. To test the robot a simple scenario is to be setup which involves a sharp U shape with two 90 degrees turns and three straight line tracks.

## Literature review

AGV is identified as automated guided vehicle, where it is capable of following a line that is positioned on the ground for specific purposes. Fotouhi[26] has developed and builds an integrated navigation strategy of a mobile robot that can move from one point to another by using a navigation system that can plan a path.[26] Yuan Yu has developed the idea for AGV by building up a magnetic map on a floor and install a sensor on a vehicle to follow the magnet, but it has an environmental problem where the sensor cannot find the location of the magnetic map, because of dimensions problems and the size of magnetic tape.[27] Jaiganesh V[28] build an automated guided vehicle for logistics purposes, and it is controlled by using a suitable program and install it in the control device. For detecting the pathway, sensors are set in AGV which is straight away controls the starting and ending process.[28] Karabegović I came up with an idea to replace workers with AGV that can work for 24 hours; it can be controlled by an automated control system, typically operated by battery, and sensors are installed to provide information on the location and the picking object.[27] In this paper AGV is suitable to be used, and it is for agricultural purposes, where the development will be focused on how the AGV can be controlled and how precise can the movement of the vehicle be. As the AGV with the sensors that is used to follow the desired path, in all the above-mentioned articles are using almost similar line following technology, however in this paper will be using a line following sensor with a sensor that can detect the colored tapes on the ground. Tanner et al.[29] explored a several mobile manipulator system holding a deformable item through an agricultural duty and the robot can hold a diversity of agricultural products.[29] Caffaz & Cannata[30] presented the first model of the DIST-Hand dextrous gripper which is basically a 4-fingered tendon operated tool that involved of 16 degrees of freedom.[30] Park et al.[31] built up an automated gripper with a specific end goal to permit control of both shape and vibration of thin-walled adaptable payloads. The gripper was designed with various impelled fingers, which contains straight actuators with DC engines and laser proximity sensors.[31] Lee et al.[32] demonstrated a service robot gripper which contains a scaled down fingertip pressure sensor, a thumb, and two fingers.[32] Ali et al.[33] planned a smart gripper that contains a vision sensor. In order to deal with the applied force, the gripper contains of two fingers accompanied by a drive sensor mounted.[33] Hatano[34] examined a sophisticated autonomous rescue robot that contains a force sensors attached on fingertips in order to stay away from breaking down rubbles throughout functioning.[34] Sam and Nefti[35] emerged an elastic robotic gripper in order to grip food.[35] Design and development of flexible robotic gripper for handling food products. In 2008 10th International Conference on Control, Automation, Robotics and Vision.

In this paper, the gripper is specifically chosen to pick and place the irrigation sprinklers and relocate it in a desire location. It is designed to have 2 fingers, which is enough for pick and place of sprinklers. In 2014 a proximity sensor and photos sensor was used in Automated Guided Vehicle by Jaiganesh, et al.[28] The proximity sensor was used to sense the AGV motion which directly controls the beginning and ending process of AGV, the main advantage of this sensor is that It avoid accident or collision. In addition the photo sensors were integrated in order to spot the object in the station.[28] Furthermore the laser range finder (LRF) was utilized for the navigation in 2014 by F Heidari & R Fotouhi.[27] It constantly provides 3D measurements of the AGV surrounding. The data is elucidated in a method that permits real time obstacle detection and avoidance for navigation of the robot.[27] There has been many researchers who were working on efficient material handling system in AGV industry. Zhou et al.[36] has worked on the most efficient ways on constructing and distributing procedures for AGV purposes.[36] They proposed that AGV can take the main role in material handling systems if the path of AGV is well planned in the field. He expanded his theories by giving some approaching lines which can be used in AGV purposes in material processing. However, the path of AGV can be improved by increasing number of sensors in which AGV can change its direction easily while being used in material handling purposes. Other studies have been done on reducing the size of AGV robots in a way that it can be applicable for any material handling systems. Egbelu et al.[37] had suggested reducing the size of AGV is the most effective way to increase the functionality of AGV in material handling systems.[37] He has been working how AGV size can be reduced without affecting its performance in any field. They implied that making AGV in square size enhances the movement of the vehicle. In consequence, size of AGV doesn't alter its performance if powerful wheels are used. Powerful wheels and motors can move smoothly in any field which make it high applicable in material handling system principles. Furthermore, effective way of installing wheels in AGV has been a controversial issue for many researchers. Muckstadt et al.[38] suggested many ways of installing wheels to the AGV which enhances the movement of AGV in material handling systems.[38] One of the ways, they proposed that AGV can be constructed using two wheels which reduces the size of AGV and increase its performance. Consequently, two wheels can be used for any AGV but the stability would be decreased. 4 wheels are highly required to promote stability of AGV while it is moving in material handling fields. On the other hand, other researchers have been arguing that 4 wheels cannot make AGV rotate. Lee et al.[32] implied some ways of installing wheels by which AGV can rotate following its line.[39] They suggested that 4 wheels have to rotate accordingly to the line following. However, there are type of wheels which can move in x,y direction freely. These types of wheels are not required to move at the edges since they can rotate in two directions. One smart idea is to install one more wheel in the middle to save AGV energy consumption.

AGV has been used for different purposes around the world. Therefore, many studies were done regarding optimizing the energy consumption of AGVs. Harlow et al.[13] proposed that reducing number of motors would enhance the energy consumption.[13] Reducing number of motors definitely will decrease energy consumption but it will impact performance. However, energy consumption can be promoted by integrating all motors in AGV together. In this paper, one motor will be used to rotate the robotic arm clockwise and anticlockwise instead of giving commands to wheels base to rotate or having additional movements. By implementing this idea, energy consumption would be notably optimized. Furthermore, Minimizing AGV weight has been one of the fundamental concepts among researchers. Koppers et al.[40] have studied the effects of AGV weight in material handling system fields.[40] They proposed a simulation model which proved that reducing AGV weight enhances AGV movement in the field. They claimed that heavy weight can impact motors movement which requires also high energy. Heavy weight requires more powerful motors which consumes high amount of energy. Therefore, chassis weight of AGV will be minimized to enhance the efficiency. Reducing number of beams also contribute on optimizing AGV weight. Thus, moderate powerful motors can be used in light weight AGVs which does not impact the movement. Other studies were achieved on to facilitate the movement of AGV in material handling fields. Tanchoco et al.[41] investigated some fundamental ways to enhance the movement of AGV in the field.[41] They proposed that high industrial sensors can potentially achieve desired outcomes. High industrial sensors can easily detect the line following. In their study, software were used which shows the differences between sensors. They had showed that some sensors take time to correspond to the received signals. However, there is a significant relationship between the mechanical and electrical responds. Some motors take time to match between the two responds. By creating well defined program, these challenges can be overcome whether the sensors are highly industrial or not. Some studies were done regarding optimizing the acceleration of AGV. Koster et al.[42] investigated the way how motors behave to reach the desired AGV acceleration.[42] They proposed that the friction between the wheels and ground can impact the acceleration of AGV. Additionally, well balanced AGV wheels installation was recommended in their studies. By installing the wheels properly, the friction on wheels will be reduced which lead to the desired outcomes. However, by promoting the material of AGV wheels can minimize the friction between the ground and wheels. Reducing costs of AGV has been significant in industry. Narendran et al.[43] we're developing some AGV structure layouts by which costs would be reduced.[43] They had suggested choosing construction AGV materials are really significant to reduce costs. Furthermore, complicated structure leads to high costs. However, simplified structure can also be controlled easily by which costs also are minimized. Thus, AGV should be constructed in a smart way which leads to minimizing costs without reducing efficiency. Another factor to reduce costs, it is to integrate the motion between all servos within the AGV. Some servos can handle more than one task instead of installing a specific servo to handle only one task. In this paper project, rather than rotating the base of the AGV to grip something, a servo is installed at the beginning of the robotic arm which can rotate clockwise and anticlockwise without rotating the whole base.

## System description and methodology

**Overview:** The methodology of constructing an AGV is a complex procedure. Certain problems which straightforwardly influence the design of the planned AGV are recorded and generally clarified. These problems are hardware as well as software problems. Software is not only constants in inputs yet it is variable and yields that must be selected to stipulate the design. Moreover, these problems cooperate with each other which cannot be considered separately, however the whole problems should be considered at the same time.[44] The points underneath will discuss about the selection of material to construct an AGV.

**Choice of material:** Movement modeling is a standout amongst the most difficult parts of designing the AGV. Movement modeling extremely relies on the area of the field, expected steering capability, location of stations and distributed track among them. Additionally, it moves toward becoming substantially more imperative if the area is small with limited moving area thus the AGV must be intended to move and make U-turns, sharp turns, curve turns and handling deviations.[45]

For the selection process the following criteria and material properties were considered:

a. Lightness
b. Strength
c. Accessibility
d. Modifiability

**Strength property:** The material should be well built and light in a similar time to guarantee the AGV is steady while in movement and that the motors can accomplish a proper proficiency. For the robotic arm, the material parts should posse sufficient quality so that the connections and bearing can withstand the energy of the servo motors, other joined connections and the payload.[46]

**Lightness property:** One approach to reduce expenses is the utilization of material parts of light weight, as the torque expected to accomplish the coveted developments will be brought down, subsequently more affordable motors can be utilized. The material as well has to be commercially available and easily cut to achieve nonstandard designs.[47]

**Modifiability property:** The material must be selected based on its simplicity of modifiability, as its frequent to go over designs and connections, that it's not standard or easy to gather. This property is imperative also because it decides if the venture or robot can be enhanced later on or not.[48]

**Accessibility property:** It is the procedure of producing items that are usable by individuals with the largest conceivable range of capabilities, functioning inside the most possible variety of circumstances. It's noticeable that the material should be available and commercially obtainable, before it's conceivable to begin the design stage.[49]

**Aluminum parts:** Aluminum parts structural components and sets fulfill every part of the above points and have consequently been selected for this project. Aluminum parts is not easily cut however this is compensated through the diversity in parts, on the other hand accurate cutting is achievable and has been achieved using apparatus such as saws. On top to this, it offers extraordinary strength and toughness,[50] as well as reliable connections which made it appropriate for the project. Aluminum parts set have been utilized with more than 35 parts as shown underneath in Figure 2, its noteworthy toughness, and its adaptability. Aluminum has key advantages in every demonstrative or experimental robotics project, in light of the fact that it can be identified with real applications.

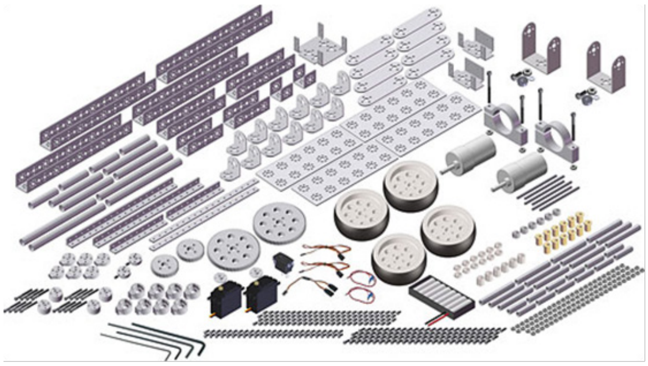

**Figure 2** Aluminum parts.[51]

## Design criteria

There are five most essential braking points which impact arrangement stage.[52] A few viewpoints are summarized below:

**Modularity:** To be able to integrate units or parts on the robot, the robot phase has to be modular. For the project, the parts to be incorporated are the gripper, robotic arm, and the AGV.

**Suitability of environmental conditions:** Robots are planned to be used in agricultural ground, which indicates that the robot have to be capable of moving off road and have the capability to conquer little bumps. In addition, electronic apparatuses on the robot must be guaranteed.

**Originality:** To contribute innovative sensible work, the robots have to be exceptional and inventive. The hardware and software arrangement of the robot have been plot by pondering into the above criteria. .

**Mechanical design:** In making movement it is for the most part achieved by mechanical engineering design which comprises of constructing a logical conclusion making strategies. Generally speaking, this particular requirement of mechanical system is focused to be accomplished, who's typically taken to be ensure their construction, operational conditions and total classification obey, the last obligation of the project action.[51] There is no restriction of scheming in mechanical system, or even a boundary to accomplish the creativeness. While giving the designers a particular requirement, each one of the designer would design something exceptional. In addition, there are several common strategies which can be useful in mechanical design. These strategies are dissimilarities of the designing procedure, and these are specified procedure or tasks to be under taken while designing (Figure 3). The most essential estimations while building the structure of the robot are: maximum and minimum dimensions; for AGV, the dimension of the length is not vital, for the width it must be among the scope of 200mm to 450mm, the height of the AGV must not go beyond 500mm. For driving the motors, wheels or any apparatus that require power which installed on the AGV must be powered by batteries, and for this situation no ignition motors. Type of wheels that require to be utilized must be big sufficiently to stay away from any movement problems.[53]

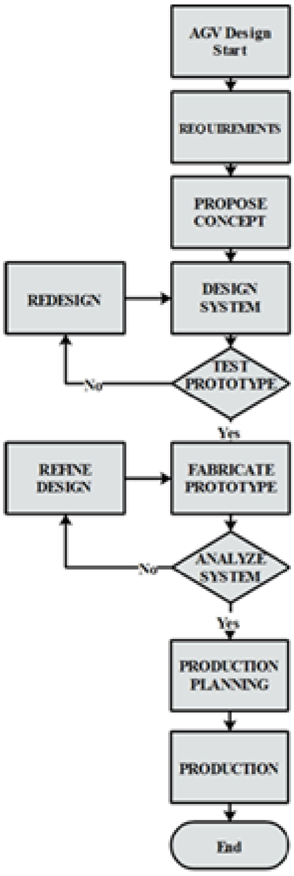


**Figure 3** Process of design.

**Engineering design:** The proposed dimensions of the AGV are as follow, the height of the AGV from the ground to chassis is 7cm, and from the ground to the top of the AGV is 13cm, the length and the width for the chassis is the same which is 28.8cm, and from the center of the front wheel to the center of the rear wheel is 21,5cm, the height of the robotic arm from the chassis is 16.5cm, the exact position from the point that the robotic arm is installed on the AGV to the point where it can pick an irrigation sprinkler is 21cm. The Figure 4 below shows the proposed 3D engineering designs with the dimensions.[54]

## AGV Body preparation with Aluminum

In order to build the structure of the AGV, Aluminum parts have been selected to be utilized in sequence to build a proper chassis. Nevertheless, to think of an immaculate and stable structure, dimensions were measured for each part that was required in sequence to be installed on the structure afterward. Sizes of the wheels, type of the sensors and the range that can recognize to detect an object, the height of the robot in view of the condition that it will work on, and different estimations should be known or very much evaluated before constructing the structure.

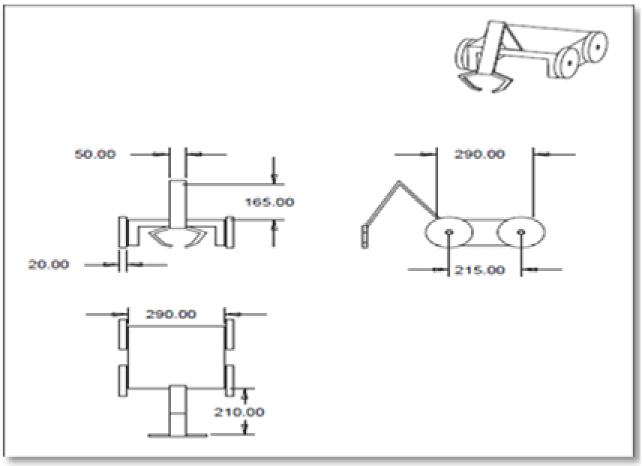


**Figure 4** 3D Engineering design.

**Motion mechanism:** TETRIX Package incorporates of 5 TETRIX OMNI wheels, this wheel is extraordinary due to its ability to move on both Y-axis and X-axis, the goal of the wheel in the center is to make the robot to move in X-axis, and the goal of the other four wheels is to make the robot move in Y-axis which are situated on the sides. Moreover it has Three DC motors, two to drive the AGV in X-axis and one to drive it in the Y-axis.

The wheels have small tires that are pasted around the AGV wheels as shown in Figure 5 below, this small tires it has the ability to change the motion of the vehicle to X-axis.

**Figure 5** Wheels.[54]

## Challenges

**Part limitation:** However, some difficulties were found while constructing the robot. The first difficulty TETRIX package does not have enough number of some parts such as Bracket servo single and DC motor mount which basically holds the motors, the solution of this was to construct and modify the same part with aluminum which helped in holding the motor.[55–60]

**Chassis balancing issue:** The problem was that the AGV was not steady and sufficiently adjusted due to the fact that one of the side wheel was not in the identical position as the other wheels and the center wheel was not situated precisely in the center of the chassis, in this manner each wheels had to be adjusted and set similarly with the other wheels and by measuring all aspects of the AGV thus each one of the wheel can be equaled and by situating the center wheel precisely in the center of the chassis which aided enhancing this issue. The motion and the construction of the AGV were fulfilled. One additional unsteadiness cause was the robot arm heaviness that has brought imbalance in the body of AGV.[61–65]

## Material handling principles for AGV

**Planning and orientation principle for AGV:** At the beginning it was not planned to have a wheel in the middle of the AGV, it was just planned to have 4 side wheels which moves the AGV according to the existing path, but after rethinking and re-discussing the decision has been made to add one more wheel in the middle of the chassis and that it be perpendicular comparing to the other 4 wheels in order to make it easier for the AGV to move in X-direction without having the chassis to rotate and move in X- direction which will consume extra work and space, therefore balancing the wheels and measuring the AGV in every side was a must in order to keep it stable and balanced. It was also planned that the AGV to pick up a sprinkler from a certain point on the tape line and relocate on the other side of the tape by using the robotic arm which has five degrees of freedom. Moreover the AGV was designed and constructed in a way so that it fit the size of the field. The design of the field needed to be appropriate and suitable for the AGV as well, in order for it move accurate and perfectly so that it does not face any issues and difficulties in its movement, so the decision has been made for the field design to be one meter length and one meter width, which is mainly three black straight lines, which basically makes a sharp U shape. Additionally it was planned from the start to use magnetic sensors in order to detect the magnetic tape which is based on the ground to move the AGV according to the magnetic tape pathway however this method was not used because it was hard to find an appropriate magnetic tape which fits this method in the region. Therefore the decision has been made to use line following sensors which can easily detect a normal black tape and move the AGV according to the black tape pathway.[66–70]

**Space utilization principle and energy principle for AGV:** The aim was to design and construct the AGV with less weight as possible and to be able to move the robot in the field without having it to consume a lot of space, so by that the middle wheel has been added to the AGV in order to move it in X direction without having it to consume more space or energy by rotating and moving to the other side, which makes it more complicated and extra effort for the AGV to move. Furthermore the chassis length and width was reduced from 488mm to 288mm so that the chassis could fit the designed field and use less space in its movement, and this change made the AGV weight to be lighter which made the servo motors to use less energy. Additionally two 12V batteries are appointed as a source in order to supply the needed energy for the motors and the main unit. They are basically placed at the rear of the chassis in order to stable the weight.

**Simplification principle and energy principle for robotic arm:** The aim of the robotic arm is mainly to grab a sprinkler which is located in front of it and relocate it to the opposite line. In this case the robotic arm was also designed and constructed in a way that its capable of rotating from right to left and from right to left without having the AGV to consume any energy, any space and it will save time as well, and for that reason a motor was added at the bottom of the robotic arm which is capable of rotating the whole robotic arm in X direction. Additionally the robotic arm length was reduced from 420mm to 210mm so that the servo motors could left the whole robotic arm with less energy consumption.[71–73]

**Cost analysis and material requirement:** Bill of materials (Table 1).

**Table 1** Bill of materials

| Part | Quantity | Price $ | Description |
|---|---|---|---|
| Servo motors | 5 | 150 | · 180 degree.<br>· Metal gear. |
| DC motors | 3 | 60 | · 12v motors. |
| wheels | 5 | 150 | · Moves to X,Y-direction. |
| TETRIX parts | 1 | 500 | · Comes with all parts needed for chassis. |
| gripper | 1 | 20 | · Two finger gripper. |
| DC motor controller | 1 | 7 | · It can control 2 same direction motors. |
| Servo motor controller | 1 | 50 | · It can control up to 12 motors. |
| Color sensor | 2 | 20 $ | · High accuracy sensor. |
| Arduino uno | 1 | 25 $ | · This is a genuine new Arduino Uno R3. |
| jumpers | 30 | 7 $ | · Elegoo 120pcs Multicolored Dupont Wire 40pin Male to Female, 40pin Male to Male, 40pin Female to Female Breadboard Jumper Wires Ribbon Cables Kit for arduino. |
| Battery | 2 | 32 $ | · ExpertPower 12V 7 Amp EXP1270 Rechargeable Lead Acid Battery |
| White tape | 1 | 1 $ | · For experiment testing. |
| Black tape | 1 | 1 $ | · For experiment testing. |

## Results and discussion

After designing and assembling the AGV, it was put to experiments to test if the projects' targets are met. For it to achieve those targets the robot had be able to follow a line with 90 degree corners to imitate a real scenario of navigation between rows of crops, and the robot has to be equipped with a functional robotic arm of five degrees of freedom with a gripper. The simple scenario as shown in the Figure 6 below was that the AGV shall follow a line with two 90 degrees corners and three straight lines; together they make a sharp U shape. But before the AGV can move, it should use the robotic arm to let the gripper reach the ground and then rise it to the initial position, this motion should be repeated at the end of the track line. After having the first experiment for the chassis, the result was not satisfactory as it was expected, because the sensor that was used was not sufficient enough and the script that was used in the arduino software was not fully functional, so different line following sensors were used which was sufficient and gave a satisfactory result by following the tape without having it to lose its track and different methods of the program was implemented which was integrated with the sensors successfully. In addition the robotic arm was under experiments as well, the result was not satisfactory as it was expected as well, where the robotic arm weight was heavy and the servo motors could not lift the whole robotic arm and the servo motors which was used were not strong enough. Furthermore the arduino software that was used was not fully functional as well, however the robotic arm was modified by removing unnecessary parts and constructing a new structure for the robotic arm and by that the robotic arm became light and the servo motors were modified by replacing the servo motors that had plastic tips with servo motors that had metal tips which is basically stronger. Additionally the program that was used was modified and integrated with the robotic arm by using different software which is mystro controller and by using different methods. Overall the results mentioned above were met successfully, but most of all the target of easy modifiability was achieved. This is because the project presents a platform that can do many different agricultural tasks by simply adding sensors or changing the program. As the AGV been under several experiments, the end of the AGV movement result turned to be a satisfactory and successful result where the AGV did not have to rotate to use bigger space in order to move on the X-axis, the movement of it was perfectly accurate by using line following sensor. In addition the end result of the robotic arm rotation on the X-axis was acceptable and successful as well, where the AGV did not have to rotate in order for the robotic arm to grab and relocate the sprinkler from its position to different position. The Figure 7 shows the final construction of the AGV.

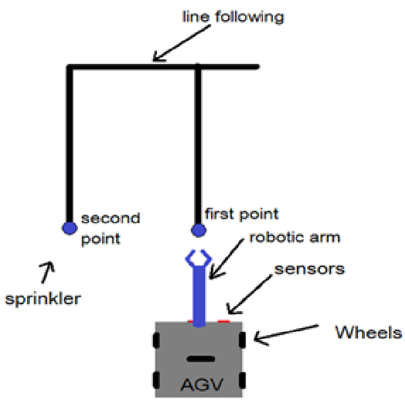


**Figure 6** Schematic diagram.

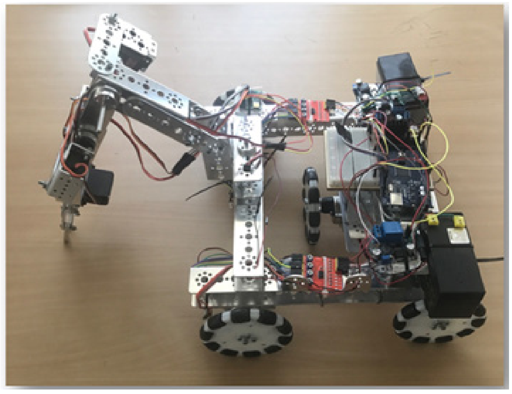

**Figure 7** Final construction of the AGV.

## Conclusion

As pointed out above the field of agriculture is confronting genuine commitments in the upcoming years, as it as it ought to encourage an exponentially expanding populace with restricted quantity of natural assets. . Robots are relied upon to assume a noteworthy part in satisfying the need of agriculture to accomplish more with less or in other words enhance the effectiveness by improving the utilization of natural assets like water and soil. This paper tries to add to the utilization of robots in agriculture by the design and advancement of an AGV incorporated with a robotic arm to supplant water system sprinkles nozzles. TETRIX has been utilized as a part of the physical development of the AGV's body structure and the robotic arm and Arduino in the controlling and programming of them. The AGV has been constructed to operate in both x and y planes by the use of five Omni tires and three DC motors. In addition the robotic arm is intended to have five degrees of freedom including a gripper which contain two fingers. A few outline criteria have been connected in the robot, most outstandingly the capacity to be adjusted by simply including sensors or changing the program. The robot has demonstrated its prosperity when it was placed under test of straightforward situation where the AGV needs to follow a black line while moving a water system sprinkle nozzle from the starting point of the track to the end of it. Material handling is needed and important part of any creative motion. Material handling essentially means giving the exact quantity of the exact material, in the exact form, at the right place, at the exact time, in the exact location and for the exact price, via utilizing the exact method in order to reduce production cost .The primary objective of it is to minimize unit expenses of production, sustain or develop product quality, promote safety and develop working surroundings and promote efficiency. Considering the material handling principles the AGV varied with most of the principles such as planning and orientation principle where it was planned that the AGV to pick the sprinkler nozzle from a certain position and relocate it on the other side of the line following tape and that the field should be a sharp U shape where the line following sensor will detect the tape and move according to the path of the tape. Furthermore it also varied with space utilization and energy principle where the AGV used less space in its movement by adding an extra wheel in the middle of the chassis and by reducing the size of the chassis and the robotic arm, which additionally reduced the energy consumption of the AGV by not having it to handle extra work by rotating or using more movements. In addition the AGV varied with simplification principle as well, where unnecessary, complicated and heavy parts were eliminated and replaced with lighter and simple parts so that the robot could be as light as possible in order for it to move in simple and easy way, therefore the servo motors will use less energy in order to move the AGV easily, which also will reduce the cost of the required parts. Furthermore by replacing lighter and simpler parts or materials for AGV it will minimize the expenses of purchasing servo motors, which will require less quantity of motors in order to move the chassis and to lift the robotic arm comparing on having heavy parts and materials which requires more quantity of servo motors.

## Future work

For the future work the material handling system principles in the AGV should be improved and modified by using different, simpler and lighter materials or to minimize the size of the chassis and the robotic arm, in order to have higher accuracy results in the movement of the AGV and robotic arm as well. And by that it must be enhanced and developed by decreasing its weight by removing unnecessary parts or replacing heavy parts with lighter parts, in order for it to move easily without having it to consume more power and more space by rotating or having several extra motions. This in addition will reduce the cost required to operate the AGV.

## Acknowledgements

None.

## Conflict of interest

The author declares there is no conflict of interest.

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