

# Towards an Automated Guided Vehicle (AGV) in Sprinkler Irrigation

Saeid Jafari, Reza Vatankhah Barenji, and Majid Hashemipour

**Abstract**—The new technologies play a more and more important role in improving the productivity over the agriculture industry. The irrigation machines as well as technologies have significant roles. Nowadays, intelligent systems and robots are employed supplementary on irrigation systems, aiming to decrease the manpower defects as well as save on energy and time. In the present work, the sprinkler irrigation classic method (moving sprinkler) is considered in detail and some of the shortcomings of this method are highlighted. Since, in sprinkler irrigation classic method after each period of irrigation the position of the sprinklers have to be replaced by manpower, this difficulty makes the method impractical from time, cost and energy points of view. The purpose of this study is to propose and develop an automatic guide vehicle (AGV) with the capability to change sprinklers timely and on appropriate positions for sprinkler irrigation classic method. The designed AGV is simulated on computer environment and the results show acceptable outcomes.

**Index Terms**—Automated guided vehicle, irrigation, agriculture.

## I. INTRODUCTION

The limitations of water resources and global population growth have led states and governments worldwide to increase agricultural products per area and optimize soil and water resources productivity with using new irrigation methods [1]. Generally, current irrigations systems are classified into pressure and gravitational systems; the pressure category includes sprinkler and drip irrigation systems and Gravitational system usually involves furrow irrigation [2]. Thus, choosing each system could maximize water productivity and minimize costs of keeping farms.

While the most region of Turkey lies in desert climate, water is the most important factor in agriculture. Therefore, in order to improve productivity, it would be possible to optimize economic efficiency through resource management and utilization of water resources at the minimum level. In comparison with traditional systems, what is expected of automatic irrigation system is decreasing water utilization without diminishing production rate [3]. Although an automatic system could meet the needs without permanent human presence and monitoring during the growing season, continual presence of the worker to control irrigation automatic instruments is not economic. Through advancements in technology and advent of processors and controllers, it will be more serious improving the role of farmer as an observer off-field particularly in the light of new

irrigation systems [4].

Human errors resulted by operators' mistakes or delays in taking required steps, which leads to reduce productivity. Thus, with waterworks development and various instruments, the under pressure units would be contortion, which are allocated the most bulk of sources. Monitoring and observing meteorological parameters, water hydraulic, quality features along with central and local precise controlling irrigation instruments, have provided an opportunity to predict and control unusual reaction of installations and also preventing accidents which lead to increasing productivity of per area unit. Moreover, management level would be able to make acute and rapid decisions depends on various conditions of utilization. Consequently, it would be provided opportunities to improve utilization management and enhance performance of productivity of irrigation units. To increase irrigation efficiency and performance of water utilization, following proceedings are suggested [5], [6]:

- Developing and adjusting modern networks of water distribution.
- Applying a scientific irrigation program according to practical requirements which are calculated in automatic systems using software.
- Using new irrigation methods regarding automation level of each waterworks unit.
- Developing, promoting and teaching irrigation methods and enhancing farmers' knowledge about the way in which systems are controlled.
- Studying cultivation patterns throughout country and changing in order to increase performance of water utilization and introducing it to software controller
- Use of AGV in irrigation

This paper reports a contribution for developing an automatic guide vehicle (AGV) with the capability to change sprinklers timely and on appropriate positions for sprinkler irrigation classic method.

## II. STATE OF THE ARTS

### A. Irrigation and Methods of Irrigation

Irrigation is the artificial usage of water in tillage process [7]. It is designed to watering plants which could be performed according certain intervals such as daily basis. It also has a few other applications in agriculture including protection of plants against icy conditions [8]. In other areas such as dust suppression, disposal of sewage, and in mining irrigation systems are also used. Generally, this process is examined together with drainage (the natural or artificial removal of extra water from a given piece of land).

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Depending on how the water should be distributed, different types of irrigation approaches are employable. One of the irrigation methods which widely use in Turkey is "Sprinkler Irrigation". There are five different types for sprinkler irrigation namely; "Sprinkler Irrigation Tumble", "Center Pivot Irrigation", "Spool Sprinkle Irrigation", "Sprinkler Irrigation Linear" and "Sprinkler Irrigation Classic System" [9].

#### B. Sprinkler Irrigation Classic System

In SICSMS method irrigation wings fixed but sprinkler are movable. For reducing expenses, big sprinkler is used that numbers of fixed Sprinkler irrigation wings are reduced significantly. This method has easier utilization, lower expense and alternative moving compared with other method. Useful life of equipment and pipes are suitable, if pipes are put inside of earth, there is no danger of theft, and also the long leg plants can be irrigated. Because, there is possibility of installation of long stand for sprinklers, for the sake of these advantages farmers welcome to this method so much and the method has developed in recent years. In this system of irrigation riser is fixed while sprinklers are connecting on riser during irrigation. Likewise, irrigation riser is separated and transferred to the next one, after each period. The main disadvantage of this method is that, the pipes are fixed during the irrigation season but irrigation risers are moved by human labor with the sprinkles which are installed on each riser [7].

#### C. Automated Guided Vehicle (AGV)

AGV is a programmable, self-controlled device consisting of electronic, electrical, or mechanical units. More generally, it is a machine that functions in place of a living agent [10]. AGVs are especially desirable for certain work functions because, unlike humans, they never get tired; they can endure physical conditions that are uncomfortable or even dangerous; they can operate in airless conditions; they do not get bored by repetition; and they cannot be distracted from the task at hand. Developed agriculture needs to find new ways to improve efficiency. One approach is to utilize available information technologies in the form of more intelligent machines to reduce and target energy inputs in more effective ways than in the past. The advent of autonomous system architectures gives us the opportunity to develop a complete new range of agricultural equipment based on small smart machines that can do the right thing, in the right place, at the right time in the right way. Advantages of AGV are as follow [11]:

- Replace human power and removes the drudgery associated with the use of human power.
- It carefully controlled the irrigation process
- High quality of irrigation is achieved as there is no tradeoff between the time and quality
- It has also low maintenance cost

The disadvantages of using AGV in agriculture as follow:

- High cost of construction
- The problem associated with assembling and disassembling after harvesting period.

### III. SPRINKLER IRRIGATION CLASSIC SYSTEM BY MOVABLE SPRINKLER (SICSMS)

This section features detailed explanation of SICSMS components, the factors that affect its design and the approach adopted during the design. Finally, advantages and short comings of SICSMS are discussed and the problem statement is introduced in detail.

#### A. Components of SICSMS

The main components of the SICSMS are as follow:

- **Pressure supply part**  
Electro pump is used direct the flow of water through the pipe to the sprinklers, in case where there is no electricity supply, diesel engine can also be used to achieve this aim.
- **Pipes in classic sprinkler irrigation**  
Transferring water from source to farms, main pipe, semi main and subsidiary pipes is used which made of aluminum, polyethylene or asbestoses. In addition, since transfer of water is from sub-surface of farm, the pipes are connected serial with the use of tee joints to direct the flow of water to the surface. Asbestoses pipes are joined to each other by asbestoses and cast iron connection. Besides, polyethylene pipes are joined by special polyethylene connection which its diameter is less than 90 mm.
- **Wings or quick valve**  
The wings are pipes made of aluminum or polyethylene material, it provides stand for installation of the sprinklers.
- **Valve and manometer**  
Pressure in pipe is partly adjusted by valve, in order for irrigation risers sprinkler to work properly; the valve is opened so that water pressure reached desired measure. Monometer is used for pressure measurement thus the indication of the amount of pressure is normally shown by the gauge. In this irrigation method, manometer is installed after pump or at the beginning of main pipe so as to indicate the amount of pressure of the sprinkler.
- **Sprinkler stand or riser**  
Sprinkler stand is such a narrow pipe that its height depends on the type of plant which is irrigated. The short stand is useful for irrigation of short plant and long stand for long plant.
- **Sprinkler**  
Each type of Sprinkler has a performance range for proper operation and these ranges must fit within the available flow and pressure criteria, both of which are a function of the water supply. Rotary Sprinkler: this is a type of sprinkler in which the sprinkler moves 180 degree or 360 degrees about an axis in-order to sprinkle the water on the farm. There are different kinds of rotary sprinkler; namely low pressure, average pressure, high pressure, extraordinary pressure.

#### B. SICSMS Design Factors

The important factors in designing of classic irrigation system are: water, energy supply condition, soil, topography condition, continent condition, product type, human power, maintenance and exploitation, under cultivation surfaces, environmental Impact. Based on the design factors, it is possible to design constant classic system irrigation.

Design factors are as follow:

- Water is supplied by a well and the quantity that flows through the pipe is determined to be  $30 \text{ l/s}$
- The quality of water must be high thus clean water is used with high PH.
- Since the water has a depth of 30 meter below the surface, to direct the flow of the water to the surface, an electric power is needed.
- Clay soil with good texture is used with PH of 7.
- Climate condition of region is moderate semi dry type.
- According to regional “plots raining”; irrigation design is done on flat surface.
- According to region, continent, soil and water and economical condition, potato is selected as the farm product.
- Required human power is semi-skilled worker.

Under cultivation surface of this land is about 60 hectare but after ratio of water to cultivated surface, only exploitable surface is calculated.

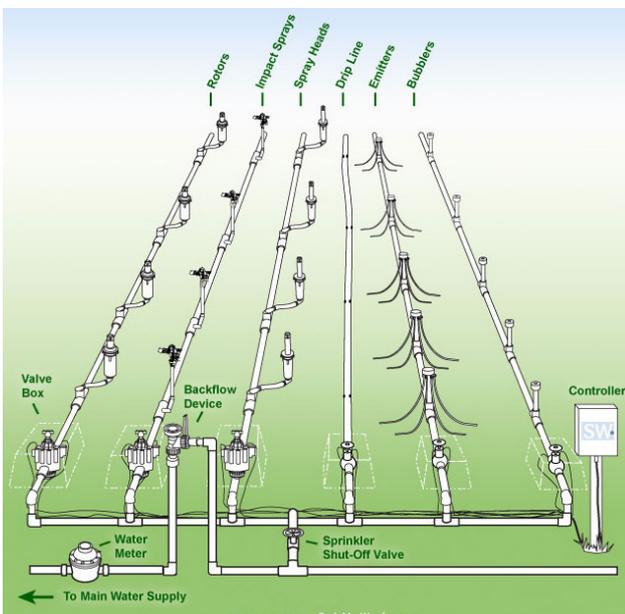


Fig. 1. Components of the SICSMS

### C. SICSMS Design

The sprinkler which is considered in this study given the intended output of 100 l/min, so it is possible to determine the number of sprinklers required for every period of irrigation, this calculation is based on the input and output rating of the sprinkler.

- Source water: 30 l/s
- Output of sprinkler: 100 l/min
- $100/60 = 1.66 \text{ l/s}$  Water output from each sprinkler
- $30/1.66 = 18$  sprinklers.

Thus using 18 sprinklers, it will be possible to reach the intended result of 30 l/s.

One horizontal electro pump is used for supplying the needed pressure, and about 5-6 atmospheric pressure is needed for each sprinkler according to clay soil condition with PH=7. To find how much water needed for the cultivation of the potato give birth to questions such

- Irrigation duration or period
- Plant water requirement after every period

Considering that the density of the potato is about 5500 per

hectare and the distance between two potato crops is 20cm and each has a depth of 15 cm approximately, the sprinkler will operate for 6 hours per day and the sprinkling operation must be repeated every 6 days base on the texture of the soil. The 18 sprinklers as installed as shown in the figure below, 6 and 3 sprinklers on the rows and column respectively, the distance between two sprinklers is 25m both on the rows and column in-order to answer the question of how much area can the 30 l/s of water irrigate.

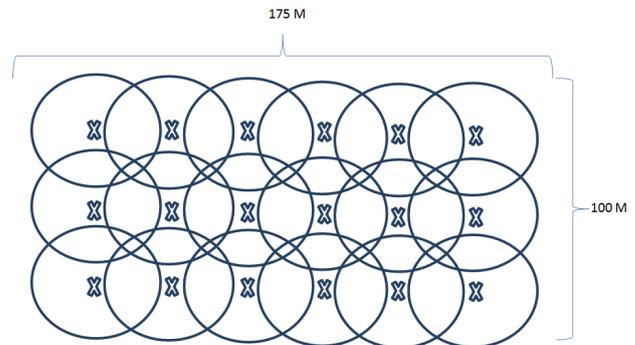


Fig. 2. The covered area for SICSMS the method

From Fig. 2 shows:

$$7 \times 25 = 175 \text{ (m)}$$

$$4 \times 25 = 100 \text{ (m)}$$

$$175 \times 100 = 17500 \text{ (m}^2\text{)}$$

This calculation, noticed that, nearly 17500 (m<sup>2</sup>) can be irrigated in 6 hours.

However, since the sprinkler radius is 25m thus every 2 sprinkler overlap with each other as they move continuously so to cover the area with the 6 hours period. The total area to be covered by the sprinkler is 17500 (m<sup>2</sup>) for every 6 hours period of operation; hence within 24 hours period it can cover 4 periods which is about 70000 (m<sup>2</sup> per day) and 20000 (m<sup>2</sup> in 6 days).

The above calculation and discussion elaborate the principles of the classic system, 18 sprinklers placed in specified location, the pump are turned on from the pumping station and irrigation starts and cover the calculated area within the 6 hours period after which the sprinklers are displace.

### D. SICSMS: Weaknesses and Short Comings

The SICSMS is most applicable irrigation method for large scale farms, but the biggest weakness in this method is on sprinklers changing process, which need a large amount of manpower as well as time have to employed in order to change sprinklers timely for appropriate positions. Since sprinklers changing process normally handling by labors, it may contain not only changing defects and problems, but also it consume huge amount of energy and cost.

## IV. TOWARD AN AUTOMATIC GUIDED VEHICLE (AGV) IN SICSMS

The advantages of introducing robots to agricultural sector cannot be overemphasized, to eliminate the disadvantages associated with the use of classic sprinkler system, such as the trade-off between duration and quality of sprinkling, energy sapping on the operators part, the use of robot becomes inevitable. This work emphasizes the application

and development of automated guided vehicle (AGV) to replace the classic sprinkler systems. This is based on explanation given in the previous sections about AGV in agriculture and the disadvantages of the SICSMS. The propose system has the capability of taking out the sprinkler from its locations after every sprinkling period and move it to another position for continuous sprinkling, without loss of time. The designed system comprises of two parts, the AGV and the moving path (rail and sensor). Fig. 3 shows shot screens of the proposed AGV.

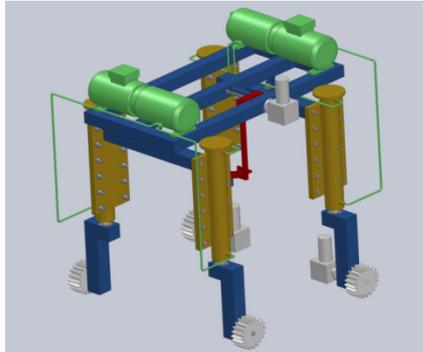


Fig. 3. 3D view of the Proposed Automated Guided Vehicle

#### A. Simulation

Consideration is given to all the factors and assumptions used in SICSMS such as soil type (clay soil with PH of 7), quantity and quality of water, types of pipes and pumps, product type, topographical configuration of the area. Instead of human power, the automated guided vehicle is used as replacement. The pipes are installed underground and foundation of length 50 cm by 30 cm width with a height of 20cm are built for the rail, on the foundation features the automated coupling value which connect the riser with the pipes, the foundation also provides support for the rail and they are fastened with the use of bolts. The two rails lines are separated by distance of 50cm and they are design in such a way to allow for line changing as in figure below.

Advantages of using rail instead of tire:

- 1) To facilitates the movement of the robot even in wet soil and worst topographic condition (non-graded land)
- 2) To decrease friction that produce drag forces, thus teeth's to provide firm grip of the robots on the rail.
- 3) It compensates for the forces of sprinkler for time of importation and exportation.

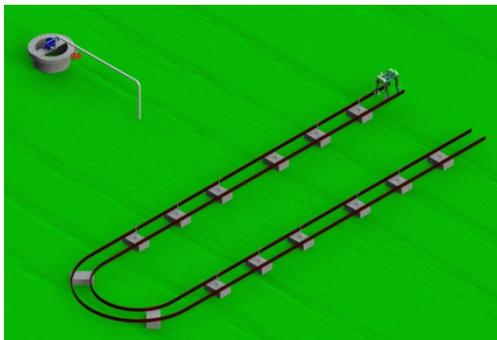


Fig. 4. The AGV path showing the foundation

Once the rails are assembled, the AGV are placed on the rail, the operators is saddle with responsibility of putting the riser and the sprinklers on the foundation just once and turning on the system from the pumping station. After six

hours, when it is time for the sprinkler replacement, the AGV identifies the sprinkler with the aid of the barcode. Based on calculations for SICSMS, 18 sprinklers acting during 6 hours period for 6 days irrigation period, to estimate the number of automated valves needed by the proposed AGV, the total operating period within six days would be 24 times multiply by the number of the sprinkler will give the required automated value of 432. Now every sprinkler has a specific automatic valve with 24 same barcode. When a robot identifies a sprinkler by the specified barcode, it takes it out of location and moves in path to identify another automatic valve with same barcode of sprinkler.

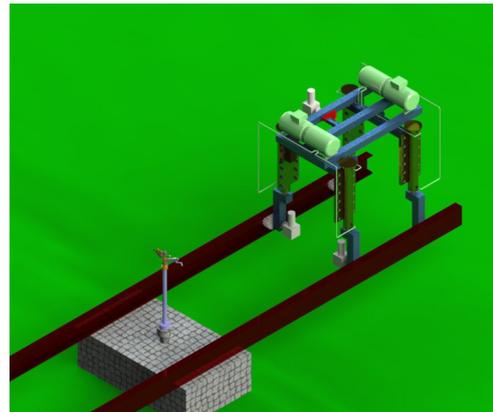


Fig. 5. The AGV path and sprinkler

The electric- motor of a spiral shaft adjusts its position toward the sprinklers .With aid of the ripper or hooks along with spiral shaft that moves to and fro, the sprinkler is gripped firmly by the moving hook.

Once the ripper hooked the sprinkler, the sensor notifies the robot and automatically the hydraulic jack moves up so the sprinkler will be detached. The spiral shaft also returns back to its formal position with the aid of electric motor while the ripper is still holding the detached sprinkler, this is necessary to avoid collision along the way as the robots moves to the next sprinkler. Once the robots identifies the automatic value control with the same barcode, Firstly, it will be stopped, then it will be guided by twisted electric motor shaft to the center of foundation and finally, hydraulic jacks will be started to go down. After reinforcement of sprinkler inside of coupling valves, static and moving jaws will be separated, in addition, jacks will go up and they moves forward for transition of sprinkler and also identifying sprinkler. After replacement of sprinkler in one line, AGV should move to the next line so in the end of line a turn back path should be used.

To negotiate a bend at the end of the path, there is a sensor incorporated that turn off one of the electric motor driving the robot, thus only one motor would be operating to enable safe turning of the AGV, after the bend has been negotiated to the other path, another sensor instructs the robot to turn the other electric motor on as it continues its movement in the other side of the path even as the replacement continues.

#### V. RESULTS

The AGV equipped SICSMS method shows the following improvements in compare with conventional SICSMS method:

- In the conventional SICSMS method, during each irrigation period (6hours), one hour lost for the changing the sprinkler. The losing time in a day is equal to 4 hour. In a complete irrigation period (6 day) this losing time is equal to 24 hours and it is also equal to 4 period of irrigation. Since, in each period of irrigation 17500 m<sup>2</sup> has been irrigated so for 4 period of irrigation this mount become 70000 m<sup>2</sup>. The area which is covered by the AGV equipped SICSMS method is 420000 m<sup>2</sup> while, this amount for the conventional SICSMS is 350000 m<sup>2</sup>.
- The simulation results show that, the AGV equipped SICSMS method has capability to rich maximum irrigated area.

## VI. CONCLUSION

The research is started with an over view about irrigation and its related methods, two category of irrigation has been explained briefly. The first category includes some traditional methods and the second one includes modern methods. One of the modern methods which are covered in this work is SICSMS method. By utilizing SICSMS method some problems encountered such as moving the sprinkles with human labor, labor should move the sprinklers after irrigation period.

An AGV has been developed and simulated, which is able to move during a rail way. Aiming to travel on this rail can detect the available irrigation in its path and remove them to their new place. The comparison between the conventional SICSMS method and AGV equipped SICSMS method highlighted that the maximum under cultivation surface is reachable by AGV equipped SICSMS method.

As a further research, it is possible to utilize RFID or wireless sensor networks instead of barcode reading to improve the controller system or AGV motion.

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