Environmental mobile robot based on artificial intelligence and visual perception for weed elimination

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Abstract: *This research presents a new editing design for the pioneer p3-dx mobile robot by adding a mechanical gripper for eliminating the weed and a digital camera for capturing the image of the field. Also, a wireless kit that makes control on the motor's gripper is envisaged. This work consists of two parts. The theoretical part contains a program to read the image and discover the weed coordinates which will be sent to the path planning software to discover the locations of weed, green plant and sick plant. These positions are sent then to the mobile robot navigation software. Then the wireless signal is sent to the gripper. The experimental part is represented as a digital camera that takes an image of the agricultural field, and then sends it to the computer for processing. After that the weeds coordinates are sent to the mobile robots by mobile robot navigation software. Next, the wireless signal is sent to the wireless kit controlling the motor gripper by the computer interface program; the first trial on the agricultural field shows that the mobile robot can discriminate the green plant, from weed and sick plant and can take the right decision with respect to treatment or elimination. The experimental work shows that the environmental mobile robot can detect successfully the weed, sick plant and the hale plant. The mobile robot also travels from base to the target point represented by the weed and sick plants in the optimum path. The experimental work also shows that the environmental mobile robot can eliminate the weed and cure the sick plants in a correctly way.*

Key Words*: Pioneer 3-dx mobile robot, robotic gripper, weeds control, machine vision, environmental mobile robot.*

1. INTRODUCTION

The global problem is the environment pollution. Nowadays we are witnessing an increasing demand for environmental protection products. The environment pollution caused by the excessive use of herbicides is one of the main reasons that cause environment pollution also having negative impact on the ozone layer. Therefore one of the most effective ways to solve this problem is using the environmental mobile robot. The use of the mobile robot in agriculture brings great benefits. Thus, the mobile robot reduces the need for the herbicides by eliminating the weed by means of a gripper.

Some of the applications of the mobile robot in the agricultural field include the following: design of the agricultural mobile robot, image processing in agricultural field and path planning of mobile robot in agricultural field [1]. The authors designed a machine vision-based autonomous navigation system for an agricultural field mobile robot; obtaining guidance information from crop row structure is the key in achieving accurate control of the robot. This paper presents a new method for robust recognition of plant rows based on the Hough transform. It used a camera to find a path from structured agricultural fields to automatically navigate a mobile robot following crop rows [2]. This work presents an autonomous agricultural mobile robot for mechanical weed control in outdoor environments. The robot employs vision systems; it has been shown that color vision is feasible for single plant identification, i.e., discriminating between crops and weeds.

The system as a whole has been verified, showing that the subsystems are able to work together effectively. A first trial in a greenhouse showed that the robot is able to manage weed control within a row of crops [3].

Herein, the authors studied changes in light intensity which causes major difficulties in the plant recognition. In order to solve this problem, this paper also started the development of a plant recognition method, with high efficiency in variable lighting conditions. This will be implemented to an autonomous mobile robot for weed control.

The method consists in determining of dependency relations between the leaves color and the light intensity [4]. This work deals with the development of near-ground image capture and processing techniques in order to detect broad leaf weeds in cereal crops, under actual field conditions.

The proposed methods use both color and shape analysis techniques for discriminating crop, weeds and soil. The performance of algorithms was assessed by comparing the results with a human classification, providing a good success rate. The study shows the potential of using image processing techniques to generate weed maps [5]. The authors discussed the problem of using navigation methods for the mobile robots in the green house. The autonomous navigation in the green house has been solved using both deliberated and the pseudo-reactive techniques.

The deliberated algorithm needs a map of the green house in which it goes to work. The pseudo reactive navigation algorithm was described joined to a sensory map building processes.

The sensors will be employed by the deliberated technique in the next run; this algorithm have been tested in a real green house by a mobile robot called fitorobot developed at the University of Almeria, obtaining quite appropriate results [6]. This paper proposed a new method of global path planning based on the neural network and the genetic algorithm; they constructed the neural network of the environment information in the work space for a robot and used this model to establish the relationship between the collision avoidance path and the output of the model. The genetic algorithm was applied to find the global optimal path in static environment. Computer simulation is given to show the feasibility of the proposed algorithm. This work consists of two parts:

The theoretical part involved building a program in Matlab to read the image, discover the weed coordination and sending it to path planning software to discover the green plant positions, weed positions and sick plant locations. Then, this coordination is sent to the mobile robots by building program in (C++.net). Next, the wireless signal is sent to the gripper.

The experimental part is represented as a digital camera that takes an image of the agricultural field then sends it to the computer to be processed and next sends the coordination of the weed to the mobile robots by C++.net. Next, the wireless signal is sent to the wireless kit controlling the motor gripper by the computer interface program.

2. GENERAL DESCRIPTION OF ENVIRONMENTAL MOBILE ROBOT

- **Pioneer mobile robot**

The Pioneer 3-DX mobile robot, as shown in Fig. 1 with onboard PC, is a fully autonomous intelligent mobile robot.

Unlike other commercially available robots its modest size lends itself very well to navigation in tight quarters and cluttered spaces, such as classrooms, laboratories, small offices.

The pioneer mobile robot platform completes with a sturdy aluminum body, balanced drive system two-wheel differential with casters or four-wheel skid-steer), reversible DC motors, motor-control and drive electronics, high-resolution motion encoders, and battery power all managed by an onboard Microcontroller and mobile-robot server software.

The pioneer Weighing only 9 kg (20 pounds with one battery), the basic Pioneer 3-DX mobile robots are lightweight but their strong aluminum body and solid construction make them virtually indestructible.

These characteristics also permit them to carry extraordinary payloads. The Pioneer 3-DX can carry up to 23 Kg (50 lbs.) additional weight [7].

Pioneer robots are composed of several main parts: 1) Deck; 2) Motor Stop Button; 3) User Control Panel; 4) Body, Nose, and Accessory Panels; 5) Sonar Arrays.; 6) Motors, Wheels, and Encoders; 7) Batteries and Power.

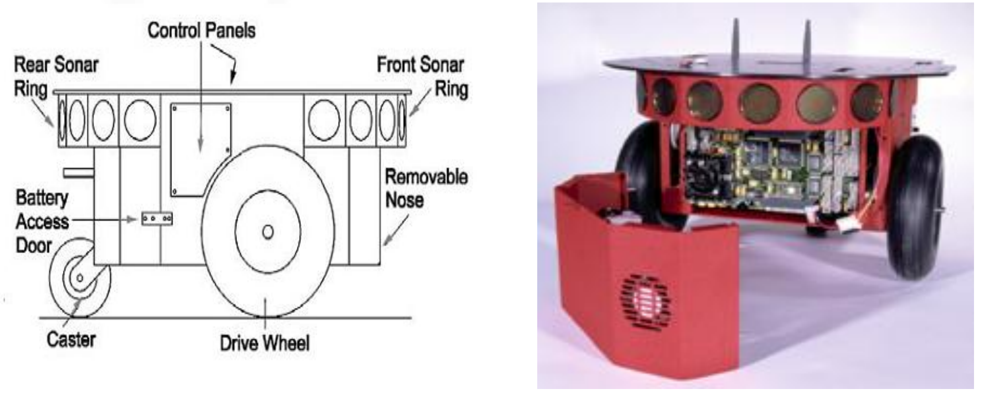

Fig. 1 Pioneer mobile robot

The pioneer platforms are servers in client-server architecture. You supply the client computer to run your intelligent mobile-robot applications. The client can be either an onboard piggy-back laptop or embedded PC, or an off-board PC connected through radio modems or wireless serial Ethernet.

In all cases, that client PC must connect to the internal HOST or User Control Panel SERIAL port in order to work [7].

- **Robotic gripper**

The robotic gripper represents a solution to the weed elimination problem. The gripper is designed by me from the scrap of the copying device. Also, I improved the design of the gripper by adding an herbicides pump because I found some of these weeds need only to be processed without elimination.

The pump will spray on the weed for healing it or some of these plants have a deep root so the robotic gripper can't eliminate the weed correctly. The base has a length of 398 mm and a width of 25 mm being linked with the other connector which has the decimator and the gears fixed on it.

The gears are connected to the arms for improving their movement of capture and release.

The gripper has a length of 40 mm and the connector between the gears and the robotic arm is of 80 mm. The diameter of the gripper circle is of 80mm.The schematic of the gripper is shown in Fig. 2.

The robotic gripper shown in Fig.3 consists of four main parts which are: 1) Base (acrylic); 2) DC Motor; 3) Gears. (Plastic); 4) Gripping arms (acrylic).

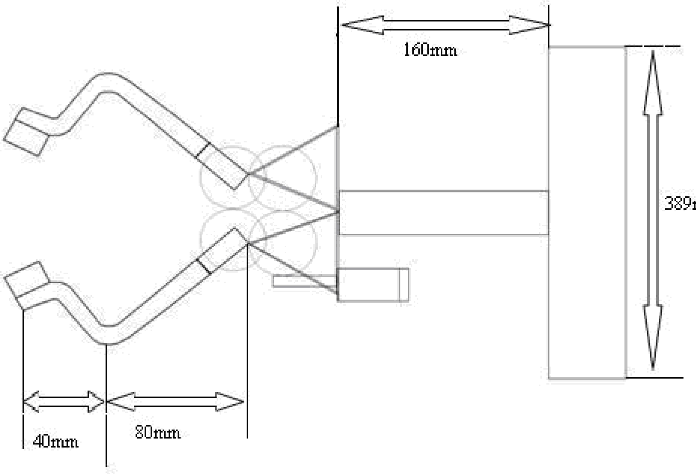

Fig. 2 The robotic gripper schematic.

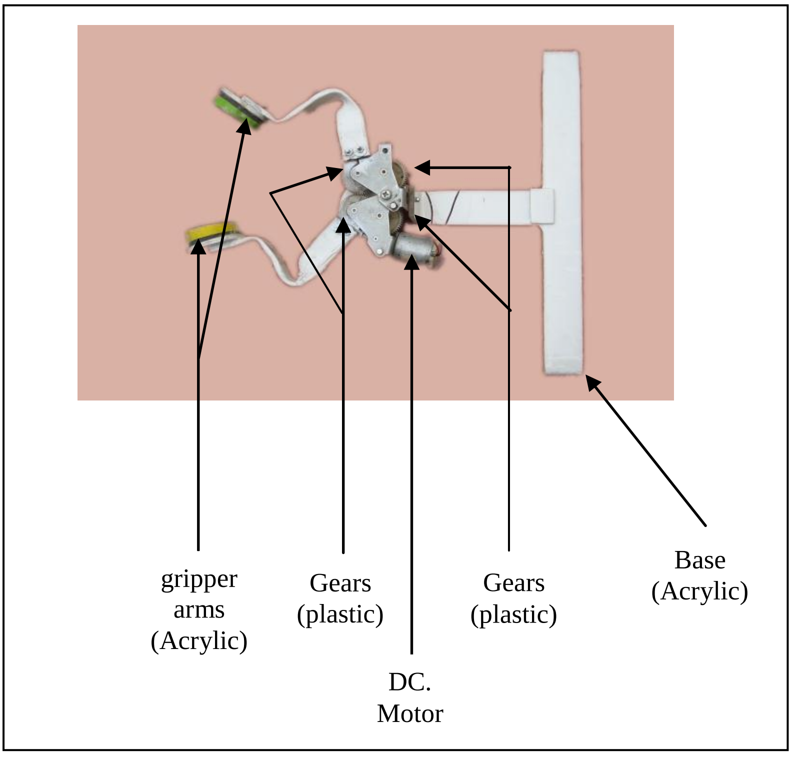

Fig. 3 Robotic gripper.

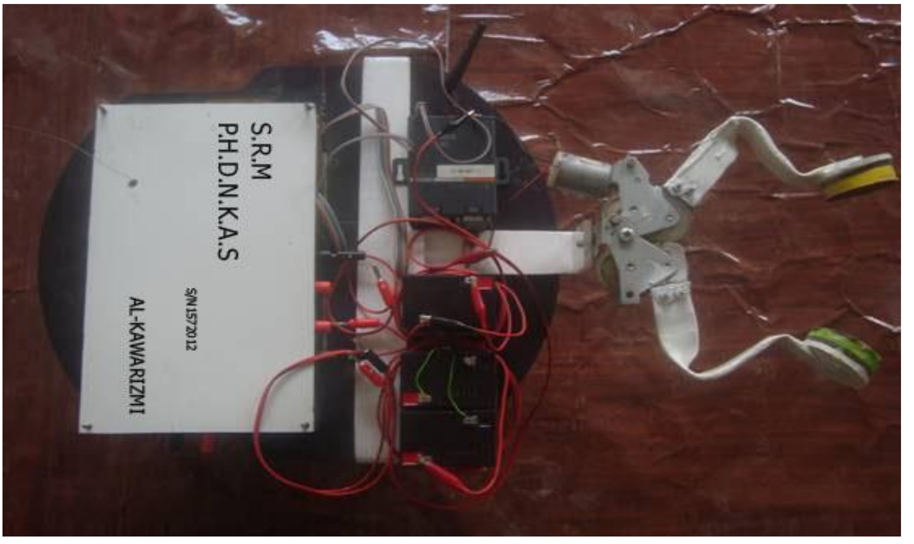

Fig. 4 The gripper fixed on the mobile robot

We also performed the design of the gripper by adding a pump motor used for the treatment of the sick plant by agricultural remedy as shown in Fig. 5

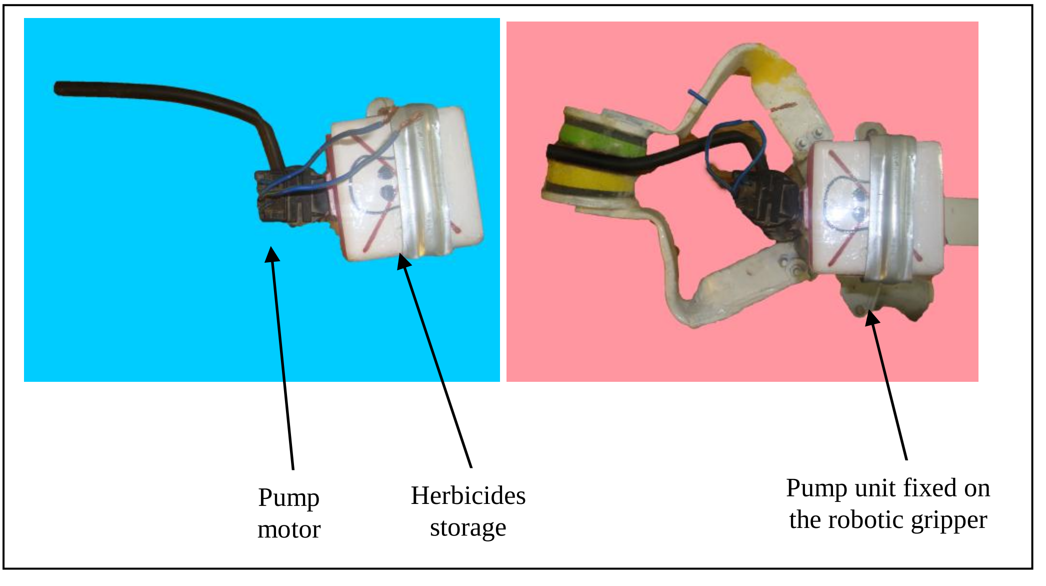

Fig. 5 The spraying unit

3. ENVIRONMENTAL MOBILE ROBOT CONTROL ARCHITECTUR

The overall structure represents the whole system of the environmental mobile robot. The PID controller and the image processing, path control model appear clearly in Fig. 6. The wireless camera captures the image of the agricultural field then sends the image to the computer to be processed. The processing process involved the image de-noising by a median filter and discriminating between the green plants, weeds and sick plants, according to their gray level. Their positions are saved in different matrixes. The path planning software receives the matrixes of position for building the environment and defining the optimum path. The position system gets the home position and the target point according to the path and the computer receives the current position that will be saved in the position system and gets command position received by the position control. The action model involved the mobile robot motor, the robotic gripper and also the pump motor of this unit. The elimination and treatment system received the wireless signal for doing the suitable process including treatment for the sick plant or eliminating for weed. To enable the environmental mobile robot to eliminate the weed and avoiding the green plant successfully according to the image for the outdoor environment the following programs are used. The Multiviewer program: used for capturing the environment image from the wireless aria. A scan camera which monitors the field where the mobile robot works in Matlab program: The Matlab (v.7.6) program reads the captured image from the multiviewer program and then processes the captured image and making a distinction between weed and plant and defining their coordination. When the environment mobile robot reaches the weed it stops at a specific distance. After the mobile robot reaches the target the Matlab initializes again to send a logic one to the wireless kit that controls the gripper motor or the pump motor. The Mobotism program: This program receives the weed and plant coordination and also the environment details (the area covered by the scan camera and the coordination of the weed and plant) to build the possible path for easy motion in the environment.

The C++.net program: This program C++.net (2003) used to run the mobile robot according to the coordination that is discovered by Mobotism.

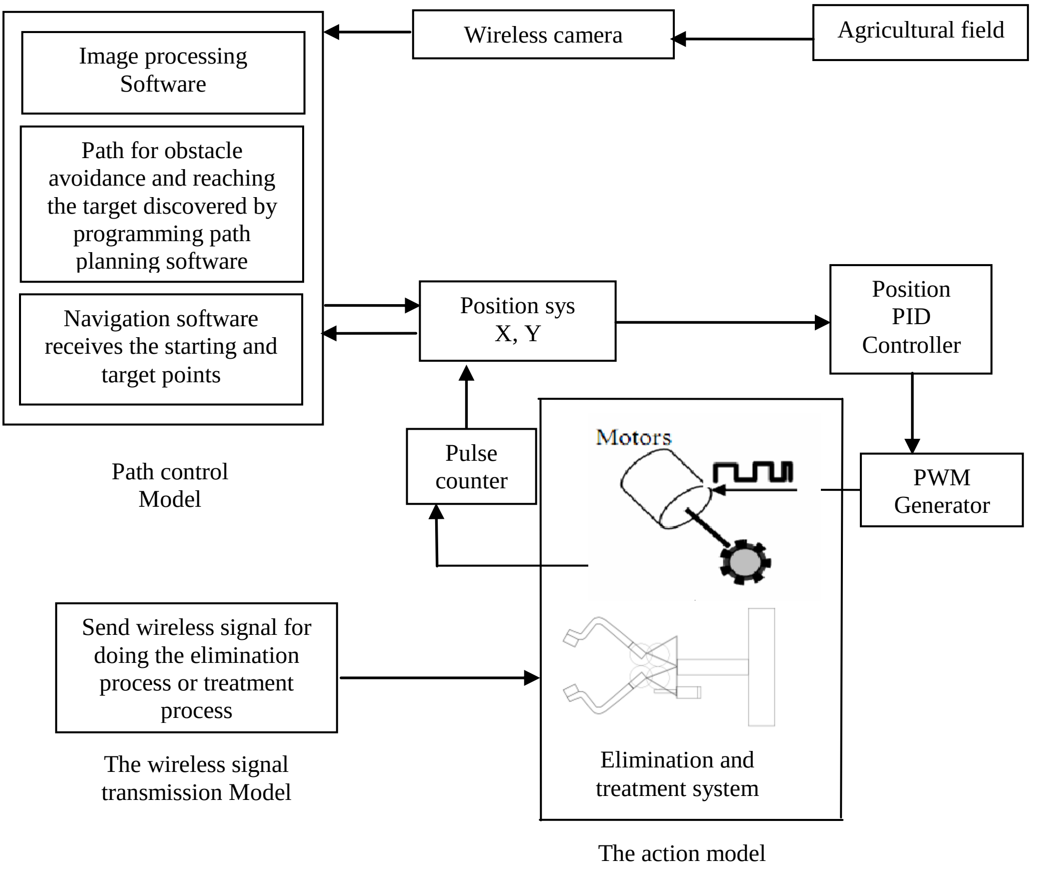

Fig. 6. The structure for the implementation of the algorithm on the mobile robot

4. THE FLOW CHART OF THE PROGRAM

The procedures of suggested method are the following:

1. Starting the wireless camera with its tuner (connected to the computer through USP connection).

2. Capturing the image of the environment by the wireless camera using the multiviewer program.

3. MATLAB program initialization.
   a. reading the captured image.
   b. removing the noise in the image by special filters.
   c. processing the image from step (b) and applying special program to discriminate between the weed and the plant then, discovering/defining the coordination of each one and saving it in specific matrix.

4. Starting the Mobotism program.
   a. receiving the weed and plant coordination from the MATLAB program.
   b. building the environment including the weed and plant location.
   c. applying special program to give all the possible and optimum paths.
   d. choosing one of these optimum paths and sending the coordination to the C++.net.

5. Initialization of the c++.net program.
   a. receiving the coordinates of the path from the Mobotism program.
   b. sending the coordinates to the mobile robot.
   c. stopping a mobile robot at a certain distance from the weed to give the gripper or the pump motor the facilities for elimination or spray.

6. Starting the MATLAB program again to the wireless kit receiver fixed on the mobile robot to catch the weed.

The flow chart is shown on Fig. 7

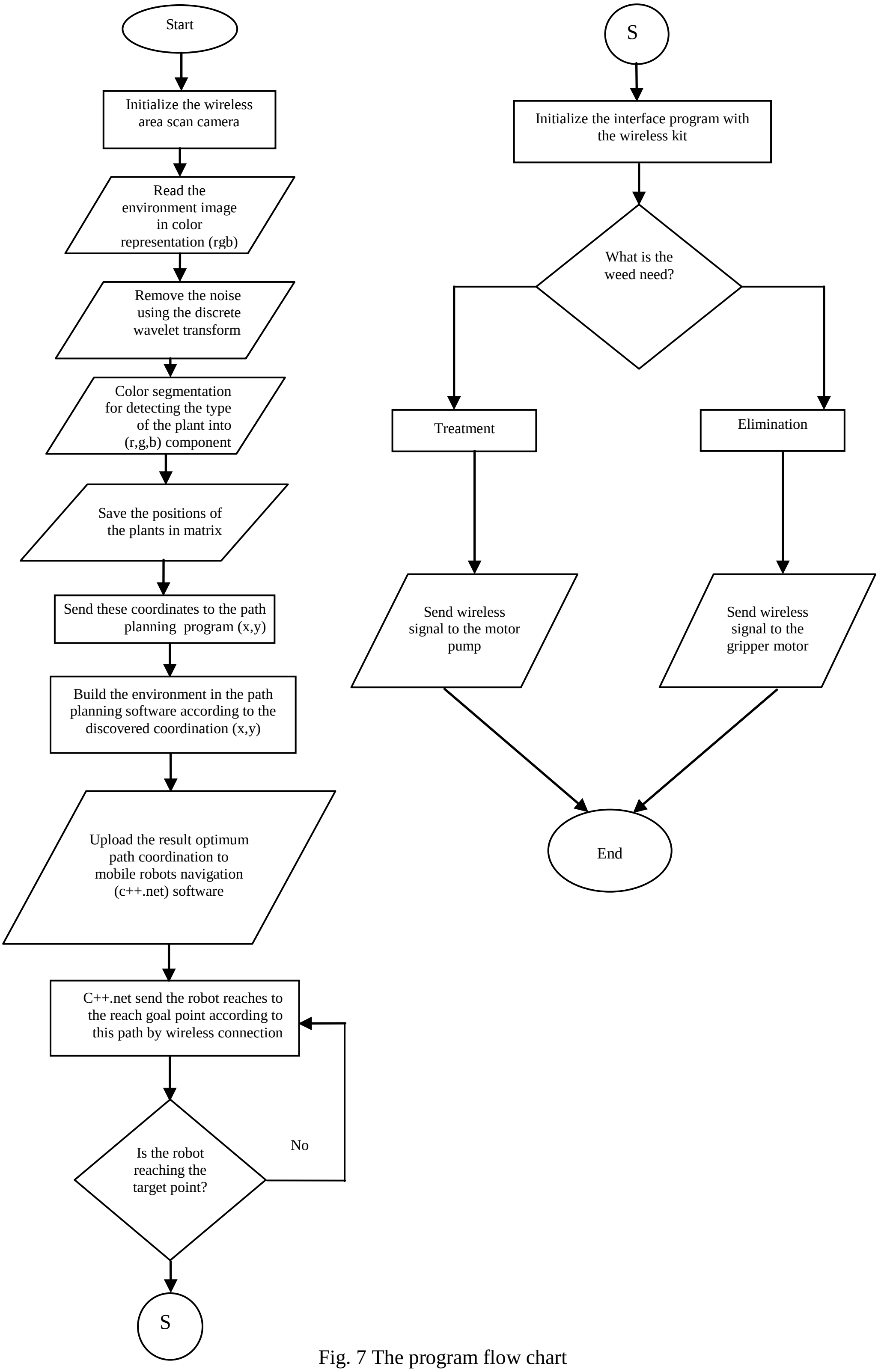

Fig. 7 The program flow chart

5. IMAGE PROCESSING

Filtering by wavelet transforms

An image is often corrupted by noise in its acquisition or transmission. The goal is to remove the noise while retaining the important signal features as much as possible. The noisy image is represented as a two-dimensional $N'N$ matrix $\boldsymbol{I(r,c)}$, where $\boldsymbol{r}$ and c are in the range $(0, \ldots, N-1)$, with additive Gaussian random noise n, as shown in the following model:

$$\boldsymbol{Y(r,c) = I(r,c) + n} \ \ldots$$

The goal is to recover $\boldsymbol{I(r,c)}$ image from the noisy image $\boldsymbol{Y(r,c)}$.

The De-noising procedure is:

1. Calculate the wavelet coefficient matrix **C** by applying a Discrete Wavelet Transform (DWT) to the data: $\mathbf{C} = \mathbf{WY}$
2. Modify (i.e. threshold or shrink) the detail coefficients of **C** to obtain the estimate $\hat{\mathbf{C}}$ of the wavelet coefficient of **I**:
3. Compute the Inverse Discrete Wavelet Transform (IDWT) to get the de-noised estimate: $\hat{\mathbf{I}} = \mathbf{W}^{-1}\,\hat{\mathbf{C}}$

The de-noising operation that modifies the wavelet coefficient differs in the choice of the threshold (shrinkage) function that determines how the thresholds are applied to the data. It differs also in the methods that estimate the noise variance of the noisy data, which is used, by various estimation methods that determine the appropriate threshold value. While the idea of thresholding is simple and effective, finding a good threshold is not an easy task. Note that the noise estimate, the threshold, and the threshold (shrinkage) function could depend on either the multiresolution level or the subband [8].

Image noise

"Image noise" is the digital equivalent of film grain for analogue cameras. Alternatively, one can think of it as analogous to the subtle background hiss you may hear from your audio system at full volume.

For digital images, this noise appears as random speckles on an otherwise smooth surface and can significantly degrade the image quality.

Although noise often detracts from an image, it is sometimes desirable since it can add an old-fashioned, grainy look which is reminiscent of early film. Some noise can also increase the apparent sharpness of an image.

Noise increases with the sensitivity setting in the camera, length of the exposure, temperature, and even varies amongst different camera models. Digital cameras produce three common types of noise: random noise, "fixed pattern" noise, and banding noise. The three qualitative examples below show pronounced and isolating cases for each type of noise against an ordinarily smooth grey background.

Random noise is characterized by intensity and color fluctuations above and below the actual image intensity. There will always be some random noise at any exposure length and it is most influenced by ISO speed. The pattern of random noise changes even if the exposure settings are identical.

Fixed pattern noise includes what are called "hot pixels," which are defined as such when a pixel's intensity far surpasses that of the ambient random noise fluctuations. Fixed pattern noise generally appears in very long exposures and is exacerbated by higher temperatures. Fixed pattern noise is unique in that it will show almost the same distribution of hot pixels if taken under the same conditions (temperature, length of exposure, ISO speed).

Banding noise is highly camera-dependent, and is noise which is introduced by the camera when it reads data from the digital sensor. Banding noise is most visible at high ISO speeds and in the shadows, or when an image has been excessively brightened.

Banding noise can also increase for certain white balanced, depending on camera model. Although fixed pattern noise appears more objectionable, it is usually easier to remove since it is repeatable.

A camera's internal electronics just has to know the pattern and it can subtract this noise away to reveal the true image. Fixed pattern noise is much less of a problem than random noise in the latest generation of digital cameras, however even the slightest amount can be more distracting than random noise [9].

Background subtraction

Background subtraction is a commonly used class of techniques for segmenting out objects of interesting a scene for applications such as surveillance. It involves comparing an observed image with an estimate e of the image if it contained no objects of interest .The areas of the image plane where there is a significant difference between the observed and estimated images indicate the location of the objects of interest. The background subtraction "comes from the simple technique of subtracting the observed image from the estimated image and threshold the result to generate the objects of interest" [10]. Background subtraction is a widely used approach for detecting moving objects static cameras. Many different methods have been proposed over the recent years and both the novice and the export can be confused about their benefits and limitations [11].

We have a field with objects that have different color and locate in various locations as shown in Fig. 8. The image algorithm as shown in Fig. 9 is based on the separate detection of the plant from the weed. The building algorithm must enable to classify each object according to its gray level. The image processing algorithm based on the segmentation to the parent gray level. Every color is the come from these gray levels.

The threshold which be chosen according to these color decides the type of the plant. Then the weed and the plant and the sick plant positions will be saved in three different matrixes. These matrixes will be used in the path planning software. The algorithm must continue to find the center of each plant. The position of the mobile robot will also be stored in other matrix. Also, the results are displayed to be used in the next program which is the path planning software.

Fig. 8. Prototype environment

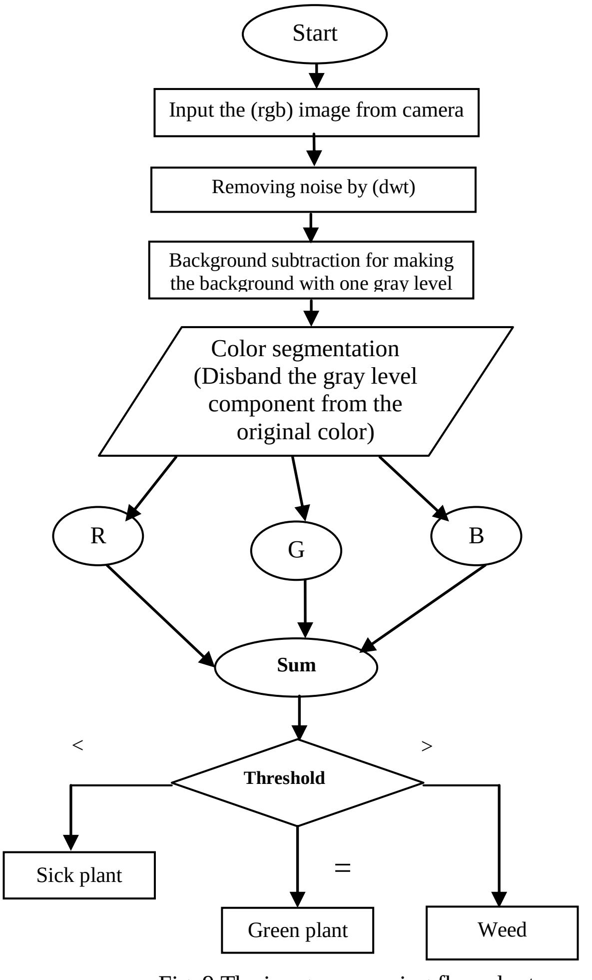

Fig. 9 The image processing flow chart

5.1. Image processing results

The size of the image is (2048x3072) and the distance is (1.8x2.49) Then, each 1cm=~140,37pixel.The environment image from the wireless area scan camera which is in colored representation and before any process, as shown in Fig. 10. As shown in Fig. 11 here we remove the noise from the image. Also, we used other technique in the program that can view the weed and plant in the same picture with different color as shown in Fig. 12.

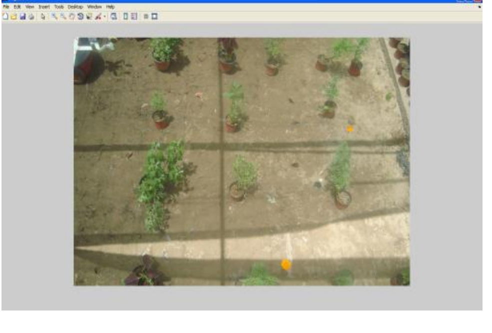

Fig. 10 Agricultural field image

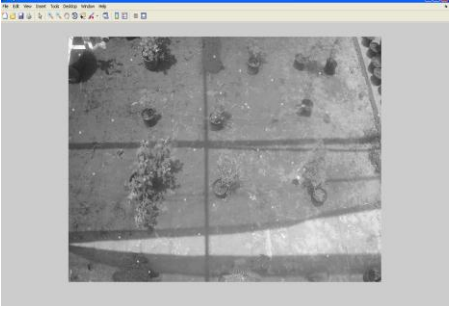

Fig. 11 The noising image.

Fig. 12 The weed gray level appears

Fig. 13 The green plant gray level

6. PATH PLANNING IN THE AGRICULTURAL FIELDS

The path planning software is based on the fuzzy logic principles. The mobile robot has a number of ultrasonic sensors located in front of it. These sensors are sensitive to any object placed behind it. Also, we can program these sensors to respond to any distance from the obstacle. They can be programmed to be intelligent and chose the good decision in other word they can be able to choose the suitable side that not contents obstacle. The result positions from the previous program can be used for building the whole environment in path planning software. The green plant must be avoided by the mobile robot and the weed and sick plant must be reported. The algorithm is based on if-then statements. This was programmed by the software. The optimum path for achieving the targets (sick plant and weed) and avoiding the green plants (as obstacle) is shown in Fig. 14.

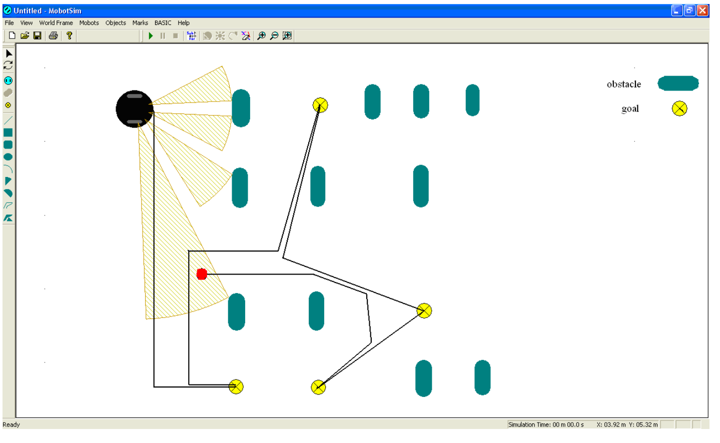

Fig. 14. Path followed by the environmental robot in the agricultural field

6.1. Path planning results

From the path planning software we understand many relationships between the paths. We can see that increasing in number of segment will increase the path length. The no. of segment increasing comes from many results that may have important effect in distance from home to target that may be reach. For example one of these results is the number of green plants and the crowded place with the green plant the figure (13) can show us the relationship between the no. of segment and the length of path which we concluded from the cases study.

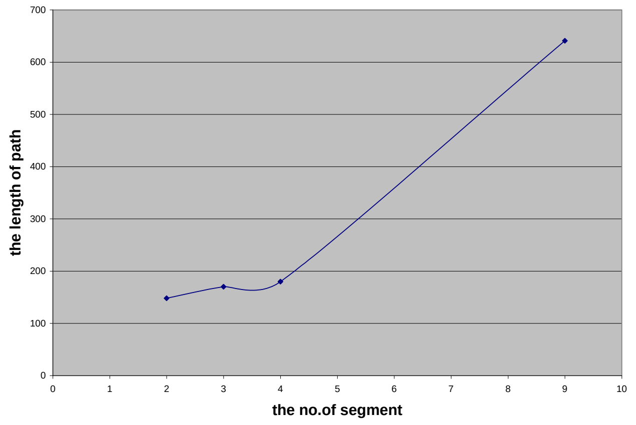

Fig. 13 The relationship between the no. of segment and the length of path

In our fuzzy logic algorithm we depend on the angle of rotation for the object avoidance and for reaching the target. The path planning software we understand that is fully depending on the fuzzy logic theory.

We take the distance from the obstacle provided by the sensors. Then the output is the angle of rotation. The fuzzy logic output from the last step (following the defuzzification) is telling the robot the suitable side for navigation. In Fig. 14 we see that the angle of rotation will be increased with the number of segments.

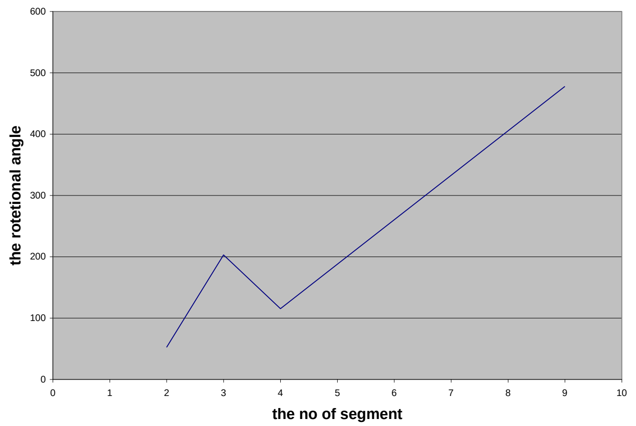

Fig. 14. The relationship between the angle of rotation and number of segment

Fig. 15 Some of treatment for the sick plant (yellow) and elimination of weed (red)

7. CONCLUSION

1. In this work we use a new path planning software, which Mobotism. It is suggested to be applied on the pioneer p3-dx mobile robot to obtain the optimum path in the static field and it can be applied in the dynamic environment by programming the camera to give instantaneous image for the field. This software provides high accuracy in the result and in the way of choosing the path.
2. The environmental mobile robot has a high accuracy in detecting and discriminating between the weed and plant, due to the best image processing algorithm programmed which deal with the each pixel in the image according to the desired criteria that the work required.
3. The environmental mobile robot behavior in the experimental work has a very good response, due to the simple properties of the wireless camera.

4. The theoretical and the experimental results. We see that they are very close to each other, this is due to the whole software working as a single unit: involving the image processing software, the path planning and navigation software.
5. The robotic gripper and the pump motor give us very excellent results, noticeable in the good elimination of the weed and the spraying on the sick plants. This can be easily performed using the wireless camera as feedback sensor to tell the robot if it is reaching the targets or not.
6. The environmental mobile robot is not restricted with a single start and targets position. From the case study we understand that the robot takes multi targets and home position and direction. This makes it able to easily enter any field and do the required operation.
7. The accuracy results in mapping between the different soft wares image processing, path planning, mobile robot navigation and the true length on the ground; this gives the accuracy of motion through the field.
8. The work independent on the available or on the ready software. The new programs in MATLAB, Mobotism and C++.net were built to give us the experimental results.

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