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Gesture Control of Mobile Robot Based Arduino Microcontroller.

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***Abstract*—The aim of this work is the control of mobile robot by hand gesture. For this purpose, the acquired hand images are treated, using algorithm based essentially on circular Hough transform, in order to define the desired targets. Thereby, the control signals are generated and sent via Wi-Fi communication to make the robot following the desired path. Test results shows the effectiveness of proposed approach.**

***Index Terms*—Image processing, Circular Hough Transform, Gesture, Target detection, Mobile robot, Arduino.**

I. INTRODUCTION

The Human-Machine Interaction recognizes in these last years a significant technological development, this new technology offers more advantages in many areas of research and applications. To realize the interaction between humans and machines, there are three major areas of advanced natural interaction for control of mobile robots in a very limited environment.

The first modality of interaction is a direct physical interaction that the human user to push the robot to move, many methods are developed in this area. Recently, the researches on Brain-Robot Interface (BRI) have been a wide interesting domain. In [1] a scheme is proposed for controlling a microcontroller using BRI. Another approach based motor imagery was developed by W. Song *et. al* [2] By exploring the activity measurement with pre-processing and processing of EEG brain signal, the first modality can be achieved.

The second modality is based on gesture to manipulate and control mobile robot, U. Rajkanna et. al developed a low cost efficient system which uses hand for controlling mobile robot which can be applied in many applications such as holding the speakers to assist dumb people [3].

In the last modality, the mobile robot is controlled in human environment via an interaction through virtual 3D lines, which are handwritten in the air by a robot user who coexists with the robot [4]. Authors in [5] proposed human gesture recognition through a Kinect Sensor (3D camera) to manipulate a mobile robot in real time.

In this paper, a new approach is proposed for target detection and location to control a distant robot mobile in real time. For this purpose, an image processing is implemented to extract the target in the different acquired images. The results of this operation is used to generate a control signal for a distant robot via a Wi-Fi communication based on an Arduino microcontroller and Arduino Wi-Fi-Shield.

II. THE PROPOSED METHOD.

A. The Material Used

In this section, we introduce a description for all of the necessary components to achieve our goal.

1) The Robot: A mobile robot is a device or an automatic machine that have the ability to move in its environment. Mobile robots can be ”autonomous” (AMR - autonomous mobile robot). They are able to navigate in an uncontrolled environment. The used mobile robot in this work which is shown in Fig. 1 has two DC motors with their gear, and two wheels balls for rotation.

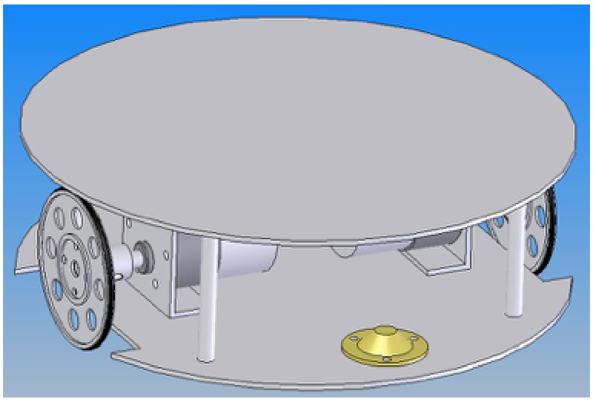

Fig. 1. Used mobile robot.

2) MicrocontrollerArduinoUno: Arduino is an open-source prototyping platform based on ATmega microcontroller [6] and Arduino uno is one of the most used boards where detailed description is given in [7].

The Arduino Uno board (Fig. 2) has 14 digital pins input/output, 6 analog inputs, a 16 MHz clock, a USB connection, a power jack, and a reset button. Generally, it contains everything needed to support the microcontroller.

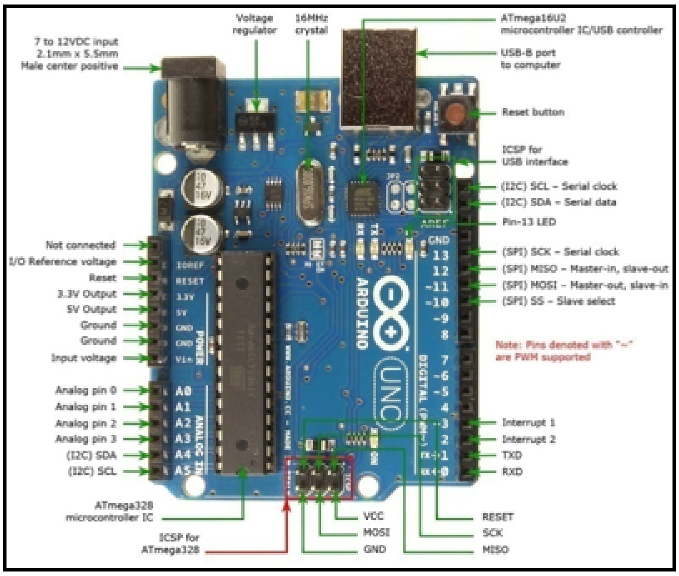

Fig. 2. Arduino Uno[7] .

3) ArduinoWi-FiShield: Currently Arduino is introduced in the most different fields for different applications. thanks to different types of shields of this device.

Wi-Fi Shield (Fig. 3) allows an Arduino board to connect to the internet using the 802.11 wireless specifications [4]. The Wi-Fi shield is connected to the Arduino board using long wire- wrap headers which extend through the shield. This keeps the pin layout intact and allows another shield to be stacked on top [4].

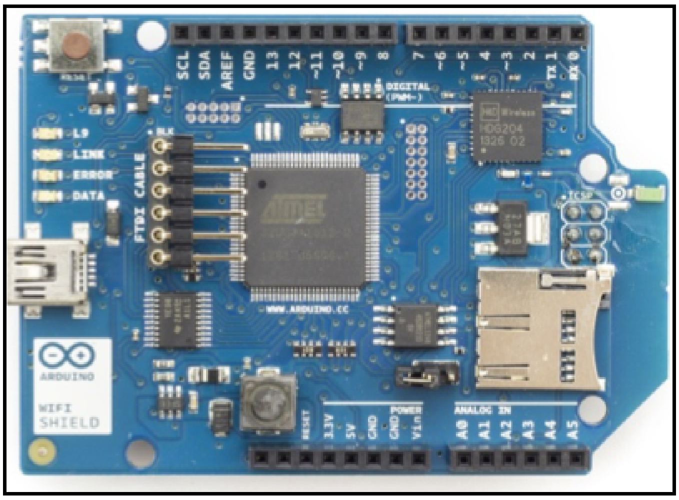

Fig. 3. ArduinoWi-FiShield

4) Hotspot(Wi-Fi): A hotspot is a physical location where Internet access can be obtained, typically using Wi-Fi technology, via a wireless local area network (WLAN) using a router connected to an internet service provider. Hotspots differ from wireless access points, which are the hardware devices used to provide a wireless network service.

5) L298 Motor Driver: The L298 is a quadruple high-current full-H driver. The L298 is designed to provide bidirectional drive currents of up to 1A at voltage from 4.5V to 36V.

B. Methodology of the proposed Approach

Our methodology is to detect and locate a target. To achieve this goal three steps are required: image acquisition, pre-processing and digital image processing. Once the target is well located, a control is operated on the two motors of the mobile robot to ensure the desired movement via a Wi-Fi connection between the processing unit and the Arduino board. A synaptic scheme of the proposed approach showing the different blocks is shown in Fig. 4.

III. SET UP OF THE PROPOSED APPROACH

Figure 5 shows the functioning flowchart of the proposed approach.

1) Stage1:Image pretreatment: For image acquisition a simple PC webcam of computer, which provides colored images of $256 * 256$ pixels, the choice of this low resolution allows us to speed up the processing of detection and location of the target, with these parameters, real time control can be reached.

2) Stage2:Image processing: Among the most common problems in computer vision is to determine the location of a particular object in an image (target). This problem can be solved using Circular Hough Transform (CHT).

To carry out the detection and localization of the target, it is called in some image processing techniques; Mathematical morphology is a tool for extracting image components that are useful in the representation and description of region and shape such as boundaries, skeletons. Erosion and dilation are the fundamental morphological operations, which are used to define the closing and opening operations.

Erosion of A by B, denoted $A \ominus B$, is defined by(1)

$$A \ominus B = \{z \;\; such\; that(B) \;\; z \subseteq A\} \tag{1}$$

Otherwise we can say that the erosion of A by B is the set of all points z such that B, translated by z, is contained in A.

Dilation of A by B, denoted $A \oplus B$, is given by(2)

$$A \oplus B = \{z \;\; such\; that(\widehat{B}) \;\; z \cap A \neq \phi\} \tag{2}$$

Otherwise we can say that Dilation of A by B is the set of all displacements, z, such that $\widehat{B}$ and A overlap by at least one element.

Opening and Closing are the two morphological operations based on dilation (opening) and erosion (closing) and they are defined by (3) and (4) respectively.

$$A \odot B = (A \ominus B) \oplus B \tag{3}$$

$$A \circledcirc B = (A \oplus B) \ominus B \tag{4}$$

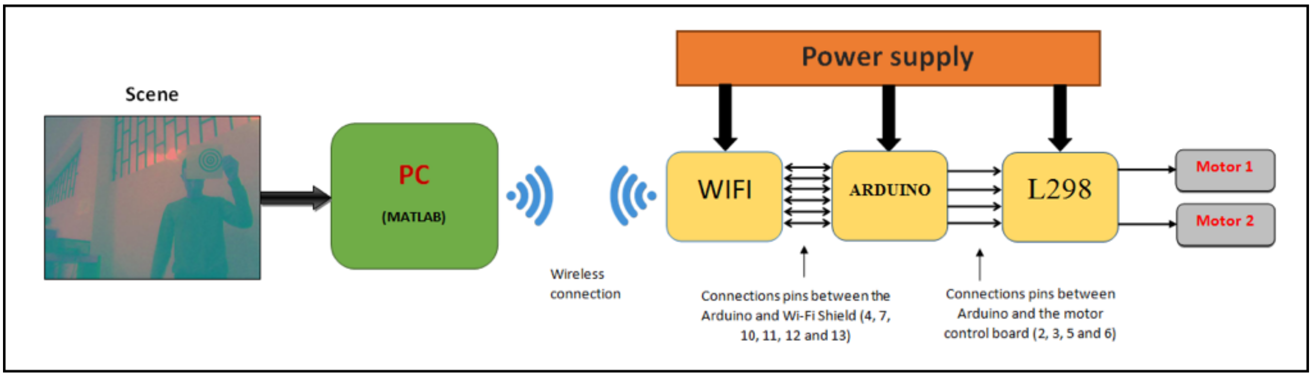

Fig. 4. Synoptic of the designed System

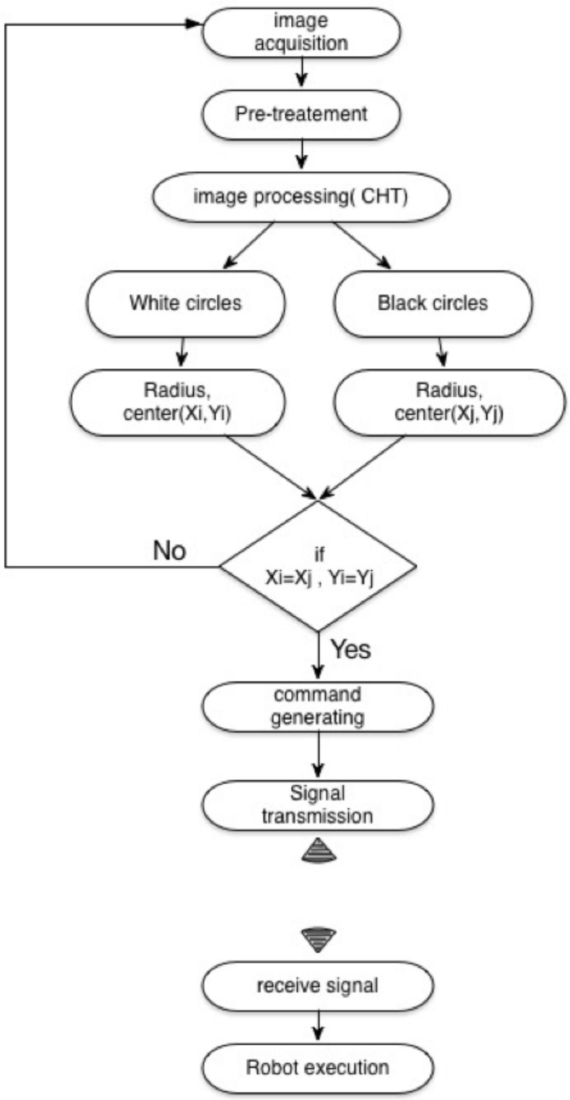

Fig. 5. Set-up of the proposed approach

The next step is to find all circular objects which using the Circular Hough Transform algorithm (CHT). This approach is adopted because of its robustness in the presence of noise and occlusion and variable lighting[8].
Circular object can be defined by equation (5).

$$r^2 = (x-a)^2 + (y-b)^2 \tag{5}$$

where a and b are the coordinates of the centre and r is the radius of the circle.

The CHT algorithm is based on three main steps: accumulator array computation, centre estimation and radius estimation [8]. Once the radius and the centre of the circular objects are identified, the target corresponds to a minimum of two white circles and two black circles with the same centre. These are the conditions that must be checked in the acquired image to consider the presence and location of the target.

3) Stage3:Generating control signals: In this stage, control signals are generated to move the robot to a position corresponding to the location of the target which is identified in stage 2. These signals correspond to the displacement and the rotation angle of the robot. To move the robot from position A to position B, the optimal shortest trajectory of the movement is calculated. An example is given in Fig. 6.

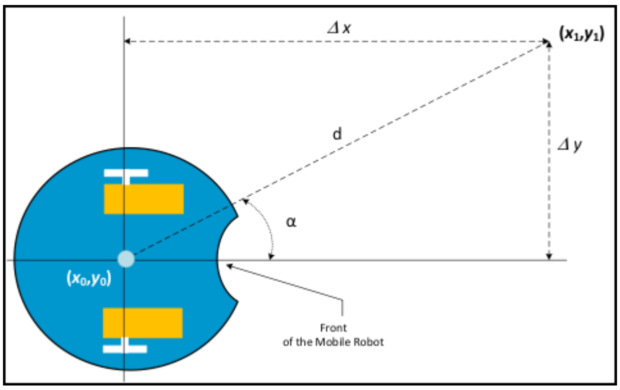

Fig. 6. Example of shortest path determination

The robot rotation angle α is obtained using (6).

$$\alpha = \tan^{-1}\left(\frac{\Delta y}{\Delta x}\right) \tag{6}$$

The distance of the trajectory is determined by (7).

$$d = \sqrt{\Delta x^2 + \Delta y^2} \quad (7)$$

4) Stage 4: Sending/Receiving control signals: Finally, comes the last step where the control signals are sent. These signals corresponding to the execution time and the rotation angle of DC motors are sent via Wi-Fi communication as follows:
$http : //IP - address/Execution - Time/Rotation - Angle$

IV. TESTS, RESULTS AND DISCUSSION

In this section, the results of the realized tests are presented. The hand given movement area of the robot is defined by the acquired image. This latter is projected on a defined surface on the ground. More clarification are given in Fig.7.

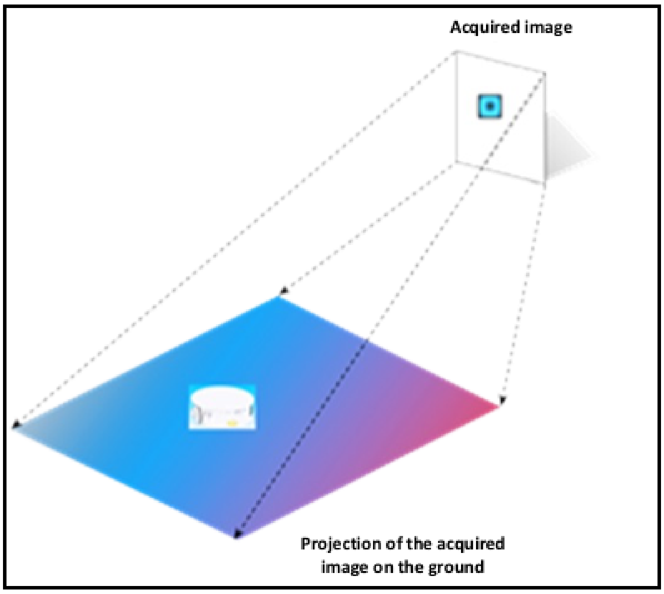

Fig. 7. Acquired image and its projection on the ground

Thus, each movement of the target in the acquired image corresponds to a motion track on the projection surface by the robot. For an image of $256 * 256$ pixels corresponds to a projection surface on the ground of $2.3m * 2.3m$. robot is characterized by an average speed of $0.83m.S^{-1}$, and a rotational speed of around $0.12rd.S^{-1}$.

Table1 shows the position of the targets, identified from acquired images, and the measurement of the corresponding mobile robot displacement in the projection surface.
Fig. 8 illustrates the path of the targets from P_0 to P_4 and Fig. 9 shows the corresponding mobile robot tracking on the ground.

Table 1 shows that the robot follows the targets on the projection surface, as an example from the position $P_0 to P_1$, the target makes a move of 70 pixels, which corresponds to a distance of $63cm$ and a real displacement of $61cm$ on the projection surface that corresponds to an error of $3.7cm$.

TABLE I
TARGET DETECTION AND ROBOT TRACKING

Acquired target (P_i)	Coordin-ates	Distance $P_{i-1}P_i$ (pixels)	Distance $P_{i-1}P_i$ (cm)	Robot displac-ement(cm)
P_0	(0,0)	-	-	-
P_1	(53,46)	70.0	63.0	61.0
P_2	(-13,49)	66.0	59.4	58.0
P_3	(48,-21)	93.0	83.7	80.0
P_4	(-8,14)	56.0	50.4	47.0

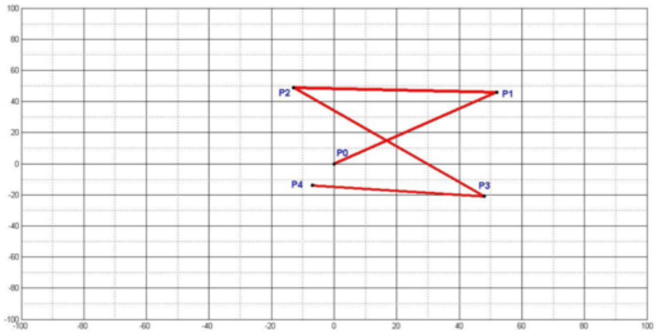

Fig. 8. Target path

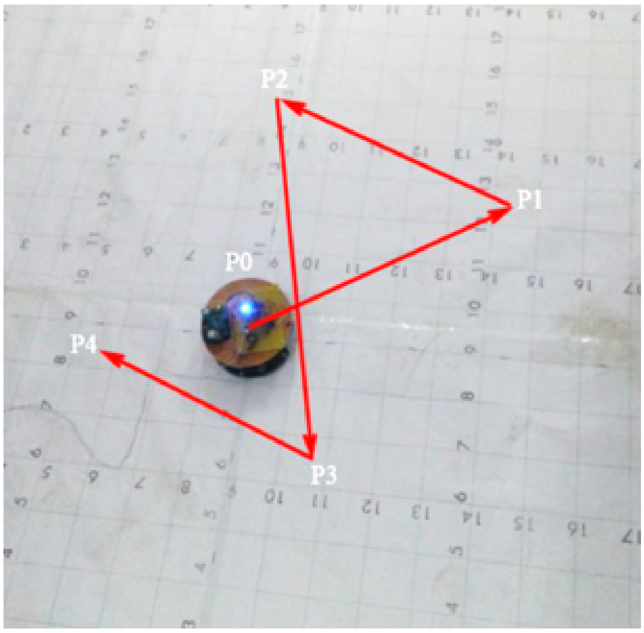

Fig. 9. Mobile robot tracking

The results of the test allow concluding that the mobile robot follows the targets, which corresponds to hand movements, in real time and makes the same corresponding gesture in the projection space.

V. CONCLUSION

In this paper, a simple approach of target detection and localization to control a distant robot mobile in real time is presented. Initially, the target extraction is done by combining pre-processing and processing techniques with incorporating mathematical morphological operators with CHT algorithm. After that, the control signal is generated and sent via Wi-Fi communication to movement actuators of the Mobile robot.

Experimental and test results shows that robot follows the hand gesture with an acceptable precision. This latter can be enhanced with improving the actuator control systems and using images with better resolution.

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