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A SMART ROBOTIC ARM FOR AUTOMATIC SORTING OF OBJECTS WITH DIFFERENT TAGS

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Abstract: This paper presents a mechatronics application to automatically sort objects with a robotic arm. The robotic arm picks similar objects and moves them in order to read the information contained in tags. In this way, the arm is able to place the objects in different final positions depending on the captured information. The starting position of a box is perceived by processing an image acquired by means of a webcam. The reading is made by using a Reader placed in a pre-fixed location inside the work space of the robotic arm. The movement of the robotic arm is guaranteed by an accurate kinematic model.

The robotic arms are widely used in industry, but most of them are programmed to follow a previously learned trajectory. Very few robots are able to make real-time decisions and so they may not be considered smart systems.

One example of smart robotic arm is provided by a device which can sort some objects taking advantage of the information contained in tags glued on the basis of the same objects. These systems can be used in several applications for protecting the environments aimed to automatize the processes of waste stocking and disposal simply differentiating the tag information.

Keywords: robotic arm, sorting objects, protecting environments, RFID, waste logistics.

1. INTRODUCTION

Solid wastes generate pollutions and other hazards to the global environment. By recycling of waste materials a lot of energy, resources and raw materials may be saved to improve environment and climate [1]. The waste sorting is the determining step in which materials with the same recycling characteristics are divided; many interesting proposal have been recently proposed using different strategies and different sensors for automating the waste sorting. Recent advances in camera technology have reduced the costs making the vision sensors appropriate for robotics and automation; for this reason scanning devices have been lately introduced for multi-visual features acquisition and pattern recognition of waste particles; in [2] a 3D camera is used for feature extraction; in [3] a robotic arm (Lynxmotion AL5A, very similar to that one used in this application) is equipped with a webcam in order to sort colored cubes; in [4] a color sensor (system-on-chip solution device) allows the driving of a SCARA robotic arm in such a way as to sort some products according to their respective colors. In [5] an overview on the solid waste monitoring is shown and an integrated system of RFID, GPS, GPRS, GIS and web camera is proposed for efficient and economic solid waste collection, demonstrating that the integration between different technologies may really become the more complete and attractive solution in automatically sorting objects.

In this paper, a robotics application is pointed out as an example of smart system where a robotic arm is driven by means of a webcam for catching a cubic box with a tag glued on its basis. Subsequently, the arm moves the box to a Reader and it identifies the object by the received information from the tag. Depending on this information, the robotic arm can take the cubic box to a deposit point or to another one in its working space. This is an example of integration between the camera feedback and the RFID technology for automatic sorting of boxes. There is to consider that the moved objects have the same shape so that the robot cannot make out their features by the webcam.

The robotic arm was suitably driven by instruction packets sent to servo-controller after solving the inverse kinematic problem. All the technical aspects on the proposed application will be given later on.

2. ROBOTIC ARM

The robotic arm Lynxmotion AL5C [6] with five servo-motors Hitec is mounted as shown in Fig.1: two servos HS-485HB for the basis rotation and the wrist respectively, one servo HS-755HB for the shoulder, one servo HS-645MG for the elbow and, finally, one servo HS-422 for opening and closing the gripper. The servos assure accurate and repetitive movements, the links are very light and the bearings minimize the friction. The servos are driven by the controller SSC-32 [6] and the driving code is on-purpose implemented; the communication between computer and controller is wireless and it is obtained by using the Bluetooth protocol (modem BlueSMiRF [6]).

Figure 1. The robotic arm

The position and the orientation of the gripper may be expressed as function of the rotation angles of the joints by geometrical considerations [7]. Naming θ_1, θ_2 and θ_3 the rotation angles of the shoulder joint (joint 1), of the elbow joint (joint 2) and of the wrist joint (joint 3) respectively, and naming θ_0 the rotation angle of the basis, it is possible to express the position of the end-effector with respect to a O(x,y,z) reference system, having the origin O lying on the basis plane. The end-effector position (x_4, y_4, z_4) is obtained by the equations (1-3) (direct kinematic arm model).

$$x_4 = [(p + l_1 \cdot \cos(\theta_1) + l_2 \cdot \cos(\vartheta_1 + \vartheta_2) + l_3 \cdot \cos(\vartheta_1 + \vartheta_2 + \vartheta_3)] \cdot \cos(\vartheta_0) \quad (1)$$

$$y_4 = [(p + l_1 \cdot \cos(\theta_1) + l_2 \cdot \cos(\vartheta_1 + \vartheta_2) + l_3 \cdot \cos(\vartheta_1 + \vartheta_2 + \vartheta_3)] \cdot sin(\vartheta_0) \quad (2)$$

$$z_4 = (q + l_1 \cdot sin(\theta_1) + l_2 \cdot sin(\vartheta_1 + \vartheta_2) + l_3 \cdot sin(\vartheta_1 + \vartheta_2 + \vartheta_3) \quad (3)$$

In (1-3) l_1, l_2 and l_3 are the lengths of each link (l_1 = 120 mm, l_2 = 128 mm and l_3 = 75 mm for the considered arm).

When the basis joint rotates, the position of the shoulder joint describes an arc of circumference with radius p. This arc lies on a plane at level q (q is the distance between the considered plane and the parallel basis plane).

The inverse kinematic problem consists in the determination of the joint variables (θ_0, θ_1, θ_2, θ_3) in such a way as to obtain the end-effector desired position (x_4, y_4, z_4) and its orientation φ. The orientation φ is the angle formed by the last link with respect to the y-axis when θ_0=90°.

The inversion of equation (1-3) has two possible solutions as regards the variable θ_2. One of the solutions is relating to a negative value of θ_2 (configuration of high elbow) and the other one is relating to a positive value of θ_2 (configuration of low elbow).

The user has to choice only the orientation φ and the goal configuration (high or low elbow); all the necessary calculations are automatically made to get information on the parameters (θ_0, θ_1, θ_2, θ_3) and to reach the desired position of the end-effector.

Moreover, the working space was examined closely and a database with some reachable positions was collected so as to define the more convenient locations for the boxes.

A Matlab code [8] has been realized in such a way as to let the end-effector describe appropriate trajectories by passing from different points in the O(x,y,z) reference system.

3. EXPERIMENTAL SETUP AND RFID TECHNOLOGY

The RFID (Radio Frequency IDentification) technology is recently becoming very important in robotics applications; the fundamental elements of a RFID system are: the TAG or Transponder (Fig.2a), a small dimension device constituted by an antenna and a microchip (inside which there is the unique identification code) and the Reader (Fig.2b, in comparison with one euro coin), used for questioning the TAG through one or more antennas.

The proposed application aims at managing the robotic arm in order to move the boxes from a starting position to a final position. The starting position is indicated with Pos.0 in the scheme of Fig.3, whereas the final position may be chosen between two different possibilities, indicated as Pos.1 and Pos.2 in Figs. 3 and 4 respectively.

These two different positions depend on the TAG signal. The Reader RFID is placed on a table and it lies on a fixed position in the basis plane (Fig.3).

The starting position Pos0 is not a fixed position, but it is estimated by processing the digital image of a webcam appropriately screwed up a rigid frame located above the table, as shown in Fig.5a.

Figure 2 a) Tag b) Reader

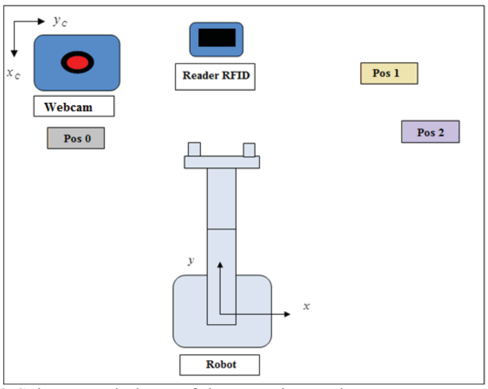

Figure 3 Scheme and photo of the experimental setup

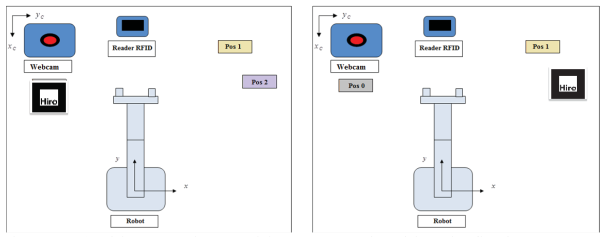

Figure 4 a) object starting position b) object in final Pos.2

Figure 5 a) the webcam used b) the considered object

The object illustrated in Fig.5b has a particular marker on its top surface, in such a way as to easily individualize the position of the object center (x_v,y_v) in the webcam reference system O(x_c,y_c) (indicated in Fig.3).

The recognition of the object position is assured by a suitable toolbox after tuning and focusing the webcam.

A reference system transformation (rotation and translation) is necessary to transform the object center coordinates (x_v,y_v) in the coordinates with respect to the robotic arm reference system O(x,y) (Fig.3).

Using the inverse model, inverting the equations (1-3), fixing the level z_t and the gripper opening, the robotic arm automatically seizes the object (Fig. 6).

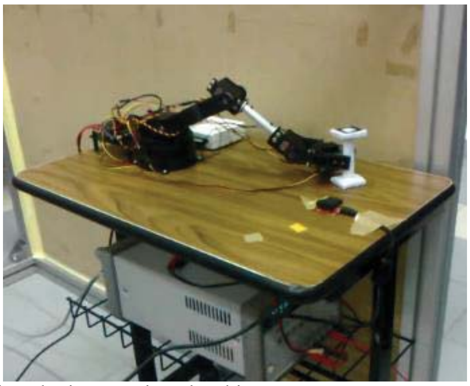

Fig. 6 The robotic arm seizes the object

The object has a TAG placed on the inferior basis (Fig.7a) and the robotic arm is programmed to let the end-effector run through a trajectory passing from a point above the Reader (Fig.7b).

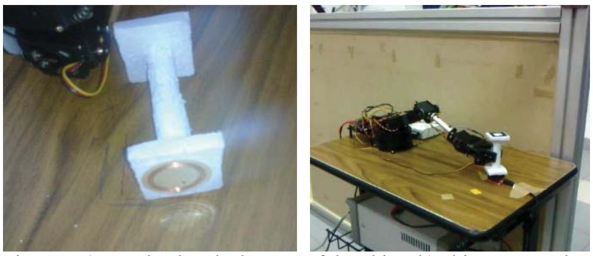

Figure 7 a)Tag glued at the bottom of the object b) object on Reader

In the experimental tests, the object was stopped in the point above the Reader for a very short time (about 0,5 seconds); this time is enough for reading the information included in the TAG and, consequently, for moving the object to the corresponding final position.

The photos of the results of one of the experiments are shown in the figures 8, 9 and 10; two identical objects are placed on the table in succession. The first object has a TAG that contains the useful information to leads it to the position named Pos.2 (in Fig.3). On the contrary, the second object has a TAG containing the information that it has to be moved to the position named Pos.1.

A human operator rests the object on a generic position on the table, similarly to what could do a belt conveyor transporting wastes in an industrial environment. All the procedure is then automatic and autonomous; the code elaborates the webcam image for estimating the position of the first object and the arm is moved to the estimated position in the O(x,y) reference system.

The end effector approaches the first object and grasps it in order to move it above the Reader.

Finally, the object is moved to its final position depending from the TAG information (Pos.2 as depicted in Figure 8 for the analyzed experimental test).

Soon after the robotic arm is moved again to the starting position and it goes to pick the second object (Fig.9) after that its position is estimated by the webcam image processing. There is to underline that the chosen final positions for the considered tests are outside the vision area of the webcam and so there is not confusion between the released object and the target one.

According to the information contained in its TAG, the second object is moved to Pos.1 (Fig.10). The entire operation is very quick and it takes only few seconds for completing all the processes.

Many experimental tests demonstrated the robustness and simplicity of the proposed procedure; there is also to consider that a single Reader may simultaneously manage dozens of TAGs, and so it could really be possible to solve the classification problem in many situations by using these cheap elements.

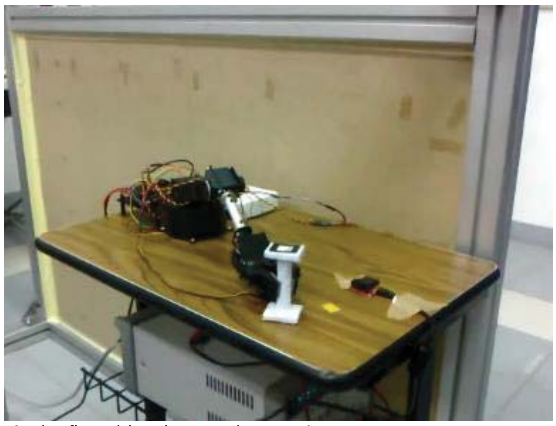

Fig. 8 The first object is moved to Pos.2

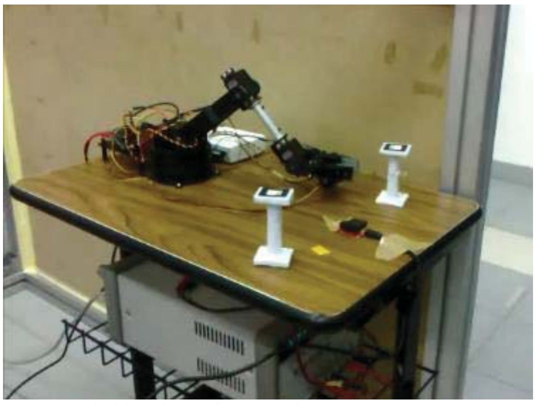

Fig. 9 A second object has to be moved

Fig. 10 The second object is moved to Pos.1

4 CONCLUSIONS

Control and verification of goods through RFID system is a matter of continuous research that can be improved by connecting RFID to the content of, for example, waste barrels and containers using magnetic properties [9], [10]. The use of this system is necessary after the characterization of container content according to common techniques like, for example, infrared for liquid analysis [11].

The proposed robotic arm was controlled by an integrated system of cheap RFID and webcam; the possibility of accurately moving it, without using any other feedback sensor, was guaranteed by a validated kinematic model, able to calculate the joint configuration in order to rotate each servo-motors and to achieve the desired end-effector position. The proposed application may be considered for efficient and economic solid waste collection as well as for sorting. The obtained good results encourages further researches to be combined with tactile robots [12].

5. ACKNOWLEDGMENT

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