The Puzzle Solver Intelligent Robot (PSR) Based on Real Time Image Processing

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Abstract: With a pressing need to upgrade productivity, manufacturing industries are turning more and more toward computer based flexible automation and robots. The need for more flexibility has led to a broad interest in the use of robots. The robot introduced in this paper is designed to solve numeral puzzles. Its control is totally by computer and has vision capability which leads its arm to certain places. In the control loop of the arm for identifying the top of the arm, image processing technique is used. Because of its polar movement on the plane, the design of the robot is considered an optimized one. The control orders are given to robot by a parallel port which obtains image from a camera through USB port. For numerical recognition a simple algorithm with the capability of learning new patterns is used. Noting that different conditions have not been given to the robot, therefore the robot is highly considered intelligent. Some of the robot characteristics include recognizing numbers by camera, 3 degree of freedom, polar movement of the plane, locating the arm of robot with the use of camera, and capability of learning simple numerical pattern.

Keword: Image processing, vision feedback, pattern recognition, adaptive control

1 Introduction

With the increasing need of production system to increase productivity, most industries are adapting flexible manufacturing system and automation.

To this extent, robots are becoming most popular every day [1]. About %35 of robot applications are in welding car body pieces in automobile industries [2].

%25 of robots in automobile industries are used to handle materials and %20 of robots are utilized in feeding, load and unloads materials.

Other important industries such as electronics, heavy industries, plastic, food, chemical, etc are also benefiting from robots [3, 4].

Advanced industries such as aerospace and marine use robotics very widely. These robots are utilized in drilling aluminum sheet, connecting pieces and setting them for riveting processes [5].

On the other hand, development of software for robots has made offline programming possible which increases the flexibility of production line.

In other term, any change in product or its related operation without setting robot individually becomes possible.

The offline programming system has progressed based on computer graphics in such away that a robot can be programmed without action to it [6].

In the shadow of this need PSR is designed so it can solve different problems in industry.

2 PSR Design and Fabrication

PSR as a new experience was made in order to be used in different industries in Iran. Different functions of PSR include Mechanical system, electronic system, and computer system (fig1).

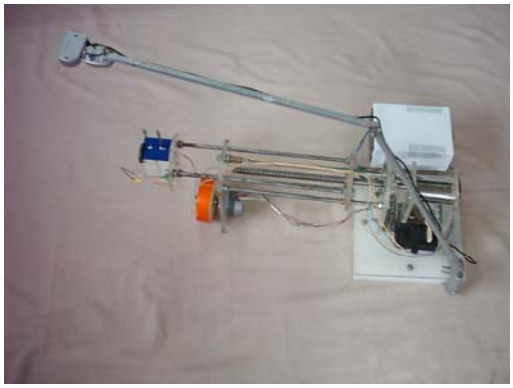

Fig1 PSR Image

3 Mechanical System

The PSR robot has a telescopic arm with a 3 degree of freedom (Fig.2). Each point in the plane is addressed by polar system.
The design of the robot is optimized using the mentioned addressing system.
The power transmition of the robot uses a worm gear system.

A DC motor coupled with a gear box moves the arm (radius). Rotation of arm (angle) is obtained by a stepper motor mounted on the arm. Puzzle pieces can be grabbed and handled by a magnet attached to arm.

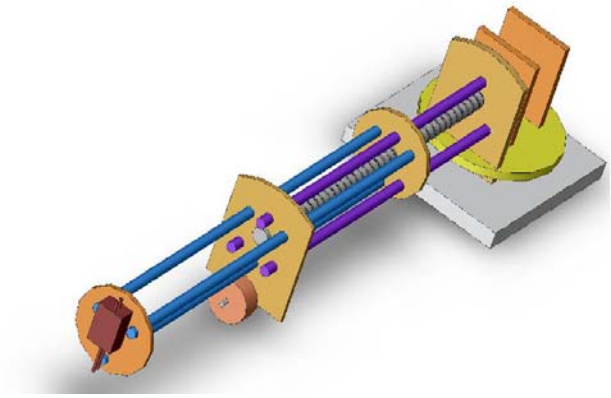

Fig.2 PSR Schematic

The solid parts of robot are made of 8mm plaxy glass connected by aluminum rods. The pivot arm is fixed in place by a heavy piece of polyethylene plate on which the control unit and the camera are installed.

4 Electronic Unit

As explained in the previous section, in total two DC motors and one stepper motor (200 steps) must be controlled. A computer is utilized for image processing and control of the robot. The control commands are issued through a printer port of the controlling computer.

The computer takes images by a web camera through USB.

Based on the designed control algorithm, the necessary commands trough parallel port is passed to the interface.

The two controllers of DC motors provide left and right motor rotation. A powerful push-pull movement for controlling motors is provided. So the robot can withstand unpredictable loads.

In order to protect the pieces during handling, the speeding up of the puzzle pieces must be limited. This action is done by Pulse Width Modulation (PWM) wave. So, speeding up or down of the gripper is controllable.

It is necessary to allocate four bits to step motor, two bits for each drivers of DC motors and one for turning the magnet off and on.

So, in total nine controls bits are necessary. Also printer port is used to control circuit.

5 Computer Programming

The PSR control program is in Delphi with a total of 1600 lines of programs. The Program's GUI is shown in Figure 3.

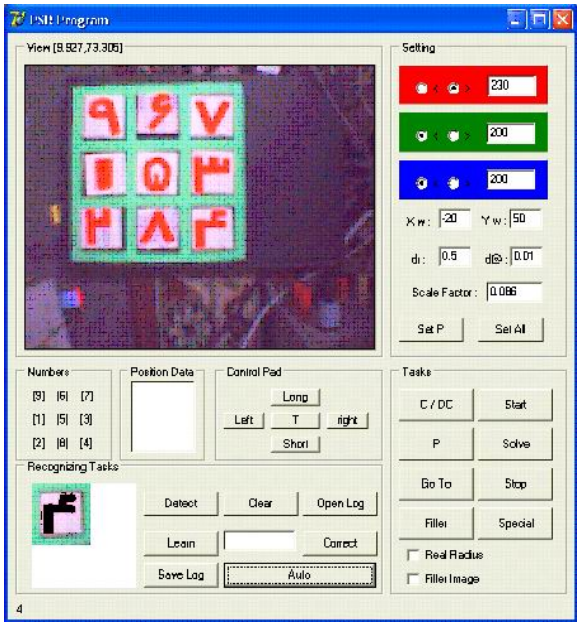

Fig3. The Program's GUI

Different sections of the Program are as follows:

5.1 Device Driver

This section consists of sub-programs written in assembly language for hardware control and access to the printer port.
Note is made that Delphi has an internal assembler so; there is no need to link the main program to other control sections.

5.2 Image Capturing

To capture images Video for Windows (VFW) technique is used.
The Tscap32 component is used to get data from camera driver through VFW. This is a free component on the internet.
The images are given as 352*288 matrix in RGB format and pass to image processing section.

5.3 Image Processor

Fig4 shows a linear system model of a typical digital image processing system.

Transfer function of each component can be modeled analytically, determined experimentally, or taken from manufacturers' specifications. The lenses, for example, can be assumed diffraction limited.
The computer operation may or may not be linear, but this is the only subsystem in fig4 that is directly under the users' control [7].

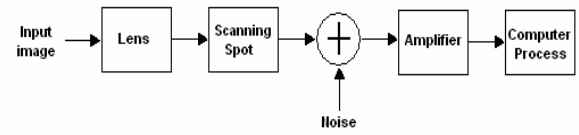

Fig 4 the elements of an image processing system

Action related to position finding (TCP) and number recognition for solving the puzzle is done by processing images captured from the camera. The camera used here is a web cam with CMOS technology.

To recognize the image elements, we used a comparison method between RGB values related to image pixels with the desired values.

Each of the amounts of R, G and B for a singular pixel can be in the range of 0 and 255. In the beginning the program appropriate amounts of the filter parameters and their application must be given to the program according to a sample frame [8].

For example to identify the yellow color the amount of the R and G must be more than 200 and amount of B must be less than 150. The color space of this process is shown in Figure5.

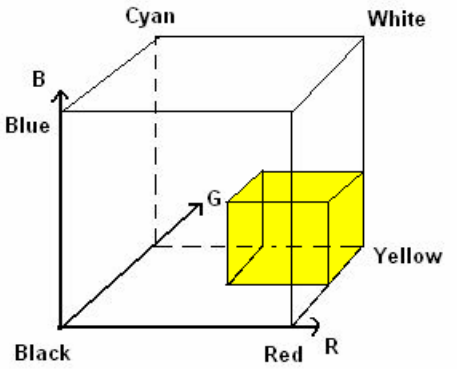

Fig5. Rectangular color space

Therefore, all the color filters are software type. After separating the puzzle, the position of each cell and the number in it, is calculated.

5.4 Number recognition

After distinguishing the number from the background, then we must recognize them.

A novel algorithm is used to recognize numbers using Figure 6 (this is 3 in Persian form), this algorithm is described.

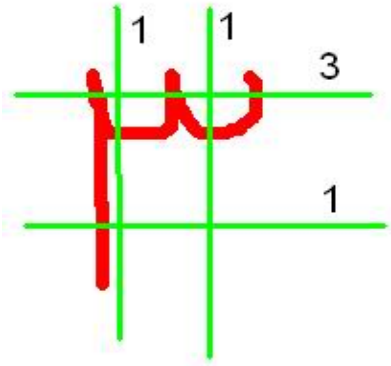

Fig6. Number Recognition Method

As observed in fig.6 the numbers of lines forming a number in different coordinate positions in the number plane are different. This is the key for number recognition in this algorithm.

For example for number 3, the number of upper limes are 3, one lines on the bottom, one line on the left and one line on the right is used.

5.5 Puzzle Solving

After determining the order of numbers in puzzle, it is enough to use a free space in the plane for solving the puzzle.

For example, if (3) was not located on its place, we must move the number in the cell outward. After finding and placing number (3) on its place, the outside number moved and placed in the position of (3).

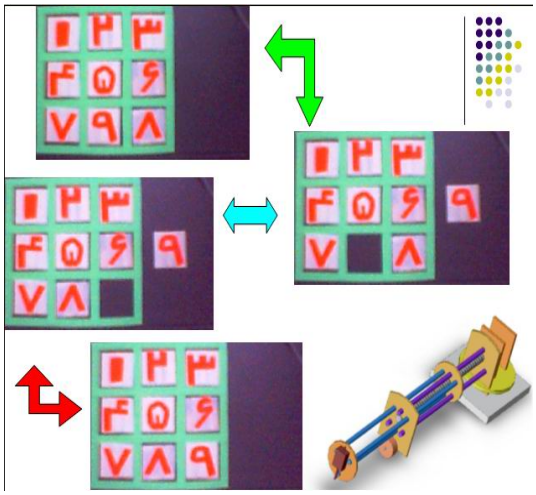

Fig.7 Puzzle Solving Method

So after performing this action for several times, the puzzle will be solved. Figure 7 illustrates this algorithm (for replacing (8) and (9) to its certain place).

5.7 Image Processing Based Close Loop Controller

After number recognition and puzzle solving, all the action that the robot must do in order to organize the puzzle will be determined.
Based on the coordinate of each numbers in the system, this procedure is prepared in the form of a G-code like commands. So, the controller loop based on coordinates will change the position of cell.

The plane is swiped once to finalize TCP. Due to the different between the TCP color and its background, its position will be determined.

Now the robot is ready to optimize the movement by considering the TCP point and the intended position. To do this, Firstly radius and then angle of the arm will increase or decrease to become equal to the optimum values of radius and angle.

6 Conclusions

In this paper different part of an intelligent robot capable of solving puzzle is explained. The coordination between different mechanical, electronics, and computer components, to meet a machine which can do various missions. In this respect, solving an unknown puzzle is considered intelligent. Utilization of image processing to feed a control loop in novel which shows the flexibility of the robot for necessary tasks.

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