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Research Article

Feedback Controlled Robotic Arm for Precision Applications

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Abstract

Puma Robot Arm-Grippers have the capability to rotate wrist-wise by 360 degrees. This independent wrist movement gives the gripper a superiority in remote surgical manouvers. Steering and positioning are frequently slave controlled. Precise positioning is limited, however, by several inherent limitations like overshoot, machine tolerance, and over actuation. Visual feedback is proposed to minimise inaccuracies in control. More precise applications can be possible by feedback control with visual inputs.

Keywords: Ergonomics; PUMA; Palletization; RTM; Robot Arm

Introduction

The PUMA robot arm has been extensively used in industry for assembly, spot welding, positioning, and placing The control of such robots has hitherto been almost exclusively under the control of programmed controllers that rely on objects that are pre-positioned as in assembly lines. Automatic correction through visual comparison of existing and desired positions remains a challenge, and in this work, it is attempted to be addressed. Robotisation by assembly-line robots has led to more efficiencies of time and scale. Efficieny has been studied since the early 1900s [1,2]. With 5 degrees of freedom (d.o.f.) and 5 independent coordinate systems and rotation axes, they can act independently of each other Actions include gripper, base rotation, arm, wrist shoulder movement. This is illustrated in Fig.1 A similar arm was constructed for instruction during a Graduate course for the Robotics syllabus of VTU Bangalore. At the time only a USB interface working on the XP platform was available. Subsequently, several attempts have been made by other experimenters to add vision and control to this kit.

Kinematics

Coordinate Systems

The motion of the arm is analysed by putting coordinate systems at the joints. The Euler coordinates are developed in the DH system [3]. "A" Matrices are used to get the system matrix. There are several alternative routes. Inverse kinematics has been suggested [4] to solve the problem. RTM (Robot Time Motion) studies are useful to minimise the overall cost.. Some programs may already have built in ergonomics. An inverse solution by the Euler angles is given [4], and Dynamics formulations in [5]. Transform matrices are described in [6]. Path control is a crucial issue in RTM. “Slewing” or simultaneously moving all joints leads to unnecessary wear for the machine. Some Programs have been given [7], for pick and place operations. In [8] they discuss ergonomical robotic movement.

Constructing assembly and running a puma 5 DOF robot

A kit was assembled as shown below.

Figure 1: OWI TAIWAN arm 5 degrees of freedom Robot.

The supplied driver works with Windows XP2. The hand moves using the computer cursor. Alternatively, control is tabs. Movements can be recorded and played back. The machine code can be stored as a program as shown here. Interpolation schemes are not available. For vision, a USB camera can be interfaced, giving 2D visual mapping capabilities.

Kinematics (Inverse)

Here, although the goal is known, unknown intervening parameters are blank. The problem is to solve backward for those angles. It can be sh6wn that the solution is not unique.

The parameters are defined in the Table 1 below.

Link	Variable	Theta	Offset	Length	Twist
1	theta1	theta1	d1	0	pi/2
2	theta2	theta2	0	l2	0
3	theta3	theta3	0	l3	0

Table 1

A program is outlined in Groover [9]

Step	Move or Signal	Comments
0	1,1	Start at home position
1	8,1	Move to wait position
2	Wait 11	Wait for press to open
3	8	Move to Pickup Point
4	Signal 5	Signal gripper to close
5	8,1	Move to the safe position
6	Signal 4	Signal press to actuate
7	1,1	Move around press column
8	1,8	Move to tote pan
9	Signal 6	Signal gripper to open
10	1,1	Move to the safe position

Table 2

Inverse kinematics has been discussed by Lin [10] where a 6 d.o.f arm is analyzed. The actions are wiping on a table with physical constraints. The stated objective was to minimize torque and disturbance. KUKA LWR robot arms were considered with dual assembly. Constraint-derived accelerations were calculated in this work, as opposed to the usual angular displacements. In the VB Approach, the camera gives 2D coordinate estimates. By mapping the arm together an error is found. Binocular sensing is needed for depth sensing and control. Optically assisted robots have also been analysed, (Ortenzi [11], Adrian [12], Amador [13], ElShair [14]). 3D capability can be constructed from many sectional 2D photographs [15].

Also another orthogonal camera on the arm or at a distance could track the motion in the third direction avoiding the use of binocular sensors. Haptic feedback can augment the coordinate-based system. "Tuning" was described by Zheng., *et al.* [16]. Ali., *et al.* [17] also discuss industrial robots with vision-based enhancement.

A few experimental setups are illustrated below.

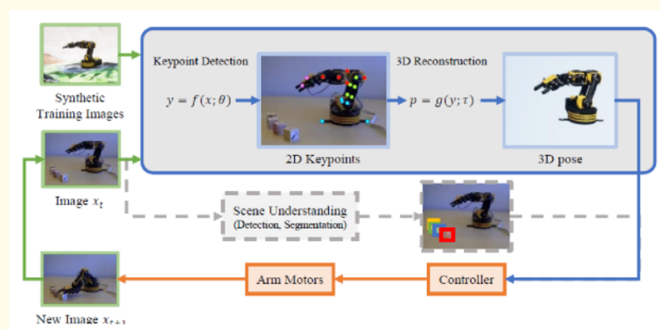

Figure 2: 2D image control (from [18]).

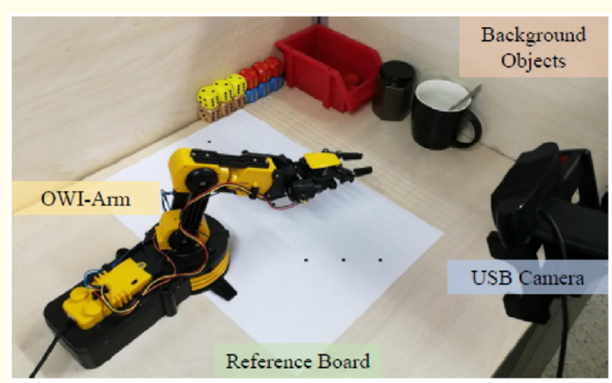

Figure 3: Setup with an external USB camera (from [18]).

Fuzzy logic can also be used in medical or nuclear handling of the tool. In critical cases of bomb disposal and other delicate explorations, binocular vision with AI can lead to more success.

A representative description of the fuzzy logic approach is shown in the figure below.

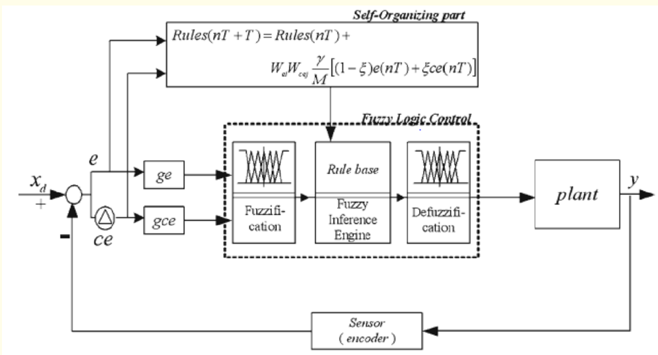

Figure 4: Self Organizing Fuzzy Controller (Huang [19]).

Analysis of ultrasound images using a neural network and support vector machines has been described by Archana [20]. Images are analyzed for medical diagnosis offline. However, the real-time on-site adaptation has yet to be described, which would be useful during vision-assisted operations.

Automated object sorting

A further application of vision-assisted sorting and processing is for Palletisation. Pallet operation is a part of many curricula. It involves repetitive movements over a conveyor belt, using a 2D or 3 D arrays. It can be done by using a loop. On CNC machines programs are generated through CAD-CAM program in Machine Language.

A sample subroutine program is attached for palletisation.

Figure 5: Palletising on conveyor belts.

Program A

1 LBL 1

2 Depalletize (229)

3 LP(3) 100 c,/sec

4 Wait 2 seconds

5 Gripper close

6 Pal_end

7 AP[4] 100 deg/sec

8 Gripper open

9 JMP_LBL 1

This sequence returns to the start point which can be suitable incremented.

A complete example program follows.

Program B

Program code	Comment
Conveyor 1 FWD	Start Conveyor 1
WAIT 20 seconds	Load workpiece
LBL 1	Start palletizing routine
R[0] = R[0] + R[1]	Increment register instruction
Conveyor 1 FWD	Restart Conveyor 1
AP[0] 100 deg/sec	Move to 1st position point
LP [1] 100 cm/sec	Move to 2nd (grip) position point
WAIT 4 seconds	Wait for the workpiece to settle
GRIPPER Close	Pick up workpiece
LP [0] 100 cm/sec	Retract to 1st position point
Conveyor 1 FWD	Restart Conveyor 1
AP[2] 100 deg/sec	Move towards pallet (3rd pos. point)
PALLETIZE (3 3 2)	Set palletize parameters
LP [3] 100 cm/sec	Move closer to the pallet (4th pos. point)
GRIPPER Open	Release workpiece
WAIT 4 seconds	Wait for the workpiece to settle
PAL _END	Close palletize parameters
IF R[0] <= R[2] THEN	Compare the contents of two registers
JMP_LBL 1	Jump to LBL 1

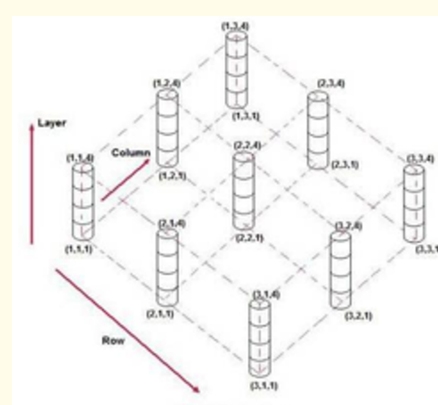

Figure 6: Stacking array for the ROBOLOGIX program (https://robologix.com/palletizing_operations.php).

Another variation is picking up an object and placing it on a conveyor belt. A refinement would need the stacked objects to be ordered in some fashion. Another refinement of the program can be embedded into a loop with 3 dimensions, provided the variables are declared and defined appropriately at the definition stage as suitable array variables. RTM analyses usually involve calculation of energies, not efficiency or the least number of steps to do a task.

When many operations are involved with multiple tasks, the power consumption has to be balanced with time and a trade-off arrived at. Palletization was studied at a factory in Taiwan during another University project during a course by al Bleihess., *et al.* [21].

Conclusion

Self-monitored, visually guided robots for delicate precise invasive medical procedures are probably yet to be developed. However, in several other areas like sorting, restaurant service, and basic maneuvering, they are already available. For developments in the field of algorithms and controls, however, it would seem that human control still appears to be dominant. There are two main streams of application, the first being the correction of the error in preset routines like an assembly line and palletization where pick and place or do-for loops are predominant. The use of guide maps or templates to locate objects with preset images is also another approach. However, the departure into autonomous decisions using AI and Neural Programs appears yet to be relied on especially in medical and other delicate operations. As emphasized, the robot is an aid to reduce human fatigue however; the human factor cannot be dispensed with.

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