Design and Development of Machine Vision Based Size Sorting Articulated Robot

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ABSTRACT

This aim of the project is to design the vision based control of the articulated robot or robotic manipulator. Articulated Robots are the most widely used robotic technology. Robots of these applications work in a strictly defined domain on strictly defined parts. There is no or very little change in such systems. Vision based control allows such systems to be dynamic. It allows the system to incorporate more changes and recover from errors. USB camera is used as a vision sensor to detect the dimensions of the object to be picked. The USB camera collects the image of the object is transferred to the python program with image processing modules to process the image. The processed dimension of the object is transmitted via serial communication to the Arduino Mega 2560 microcontroller. The appropriate PWM signal is generated by Arduino respectively to the servomotors. The robotic arm is designed with servomotors and 3D printed parts. Open source computer vision (Open CV) is used for real time capturing the image to process the image captured by the USB camera to find the exact dimension of the object thereby to assist the robot to sort it based on size.

KEYWORDS

Articulated Robot, Machine Vision, Image Processing, Arduino Microcontroller, OpenCV, Python

1. INTRODUCTION

An Articulated robot is a robotic manipulator, designed with different Degrees of Freedom depending upon the autonomous application where it is sorted. Now a day's several industrial automation are carried out with Robots such as arc welding, automobile manufacturing industries makes use for painting and engine assembling. The robots is to serve as a human in the industrial environment requires unique combination of embedded system architecture with its mechanical design. Among them the actuators implemented with the robotic arm designs are more consciously chosen. In general all motors fall under the category of actuators, the motors are widely used with the construction of robotic arms. The motors more appropriate to be used as its unique way of rotation characteristics. So, an entire mechatronic system would frame the robotic arm. The DOF of any robotic arm defines the ultimate efficiency equivalent to a human. Number of motors usage is dependant of the application for example in this proposed work the system is developed for a pick and place application. Therefore the robotic arms are enabled with high torque motors to pick and move objects to new location. Three major parts of the robotic arm gripper, wrist and base are constructed with the motors. The functioning of motors and working of robotic arm is discussed. The mechatronic design is completely capable of doing the defined job on the fields but it has to be monitored periodically to avoid some issues. The robotic arm is constructed with a Arduino microcontroller which thereby has provisions to interface with a PC. The microcontrollers interfaced with the PC works dynamic in bidirectional way to get input from the PC and provide control signals as output to the servomotors which controls the robot. This is the usual case in the autonomous systems previously; this system design proposed is developed with vision sensor – USB camera to assist the articulated robot in absence of human and make the entire system as fully automated closed loop system. The USB camera captures the image of the object to be picked and move to new location. The captured image is further processed with Image processing python libraries which are running on PC with Open-CV, pyserial modules. In this paper different python modules are used to measure the exact sizes of the object. The technologies used in the vision based control of the robotic arm or robotic manipulator. Robotic arm is the most widely used robotic technology. It is used in many industrial applications, but majority of these applications are single purpose. Robotic arms of these applications work in a strictly defined domain on strictly defined parts. There is no or very little change in such systems Vision based control allows such systems to be dynamic. It allows the system to incorporate more changes and recover from errors.

The concepts of Robotic Vision are also discussed. The camera is the main sensing equipment in such systems and has two main configurations eye-in-hand and eye-to-hand, as discussed. The specifications needed for the camera in such applications are also discussed. Other important requirements of most robotic vision systems are also discussed in this paper, which include the light; the equipment required like films, storage media etc.; and the processing capabilities required to interpret the feed. Implementing vision in robotic manipulators also has its challenges like working conditions, the speed of data transfer and handling such data [1]. The design, development and implementation of robot arm, which has the talent to accomplish simple tasks, such as light material handling. The robot arm was designed and built from acrylic material where servo motors were used to perform links between arms and execute arm movements. The servo motors include encoder so that no controller was implemented; however, the rotation range of the motor is less than 180º span, which greatly decreases the region reached by the arm and the possible positions. The design of the robot arm was limited to four degrees of freedom since this design allows most of the necessary movements and keeps the costs and the complexity of the robot competitively. The end effector is not included in the design because a commercially available gripper is used since it is much easier and economical to use a commercial one than build it [2].

The design of vision assisted pick and place robotic Arm. The main objective of the paper is to pick and place an object from one place to other by 2 DOF robotic arm. USB camera is used as a vision sensor to measure the dimensions of the object to be picked. The USB camera collects the image of the object is transferred to the LabVIEW API with image processing toolkits and modules to process the image. The processed dimension of the object is transmitted via RS-232 serial communication to the microcontroller LPC2129. The appropriate PWM signal is generated by LPC2129 respectively to the servomotors. The robotic arm is designed with servomotors. Digital image processing algorithms are implemented to process the image captured by the USB camera to find the exact dimension of the object thereby to assist the robotic arm to finest. NI-IMAQ - Machine vision based functions are implemented [3]

2. Hardware Description

The main objective of this paper is to visually track the object and transmit the image to PC running python programming to find out the object dimensions and send the appropriate control signals to the Articulated Robot via Arduino microcontroller to pick and place the object and sort them at expected location from unknown location. The system can be controlled by Python and Arduino Mega in PC.

The overall system articulated robot was designed using solid works 3d cad software and a 3D printer. The material used is Polylactic Acid (PLA) a biodegradable polymer and has characteristics similar to polypropylene (PP), polyethylene (PE), or polystyrene (PS). It can be produced from already existing manufacturing equipment (those designed and originally used for petrochemical industry plastics). This makes it relatively cost efficient to produce. The total system was controlled using three stepper motors and stepper motor divers. The stepper motor torque is 3.2Kg.cm. with 1.8° step angle (200 steps/revolution).

2.1. Bearings

A bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts. The design of the bearing may vary, for example, provide for free linear movement of the moving part or for free rotation around a fixed axis; or, it may prevent a motion by controlling the vectors of normal forces that bear on the moving parts. Most bearings facilitate the desired motion by minimizing friction. The type of bearing used in this are Radial Ball Bearing (624ZZ), Flanged ball Bearing(F686ZZ), Thrust ball bearings(51105).

2.1.1 Radial Ball Bearing (624ZZ)

This Radial Ball Bearing 624ZZ for 3D Printer/ Robot is a 4x13x5 mm Double Shielded Ball Bearing with 624ZZ ABEC-3 quality, 624ZZ Bearings are the popular item that could be used in many application that uses this size 4x13x5 mm bearings, each 624ZZ bearings are closed with 2 Metal Shields, one Shield from each side, to protect the bearing from dust or any possible contamination.

Figure 2.1: Radial Ball Bearing

2.1.2 Flanged Ball Bearing (F686ZZ)

F686ZZ Flanged Ball Bearing, F686ZZ Bearing is made of Chrome Steel, the bearing is metal shielded from both sides. It has a 6mm inner diameter, a 13mm outer diameter, a 5mm thickness, and a 15mm flange. Ball bearings of this size are ideal for precision work and applications that require a lot of functional mechanical parts, such as mechanical equipment, electrical instruments, toys, doors, and windows.

Figure 2.2: Flanged Ball Bearing

2.1.3 Thrust Ball Bearing (51105)

51105 Thrust ball bearing SKF Single direction thrust ball bearings consist of a shaft washer, a housing washer and a ball and cage thrust assembly. The bearings are separable so that mounting is simple as the washers and the ball and cage assembly can be mounted separately Single direction thrust ball bearings, as their name suggests, can accommodate axial loads in one direction and thus locate a shaft axially in one direction. They must not be subjected to any radial load.

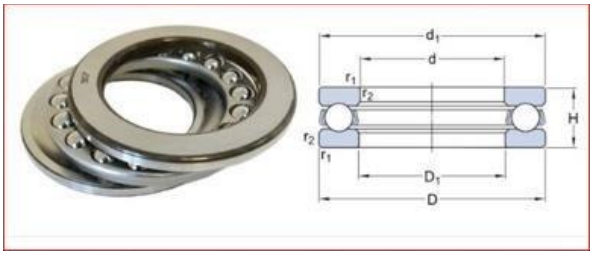

Figure 2.3 : Thrust ball bearing

2.2 Stepper Motor Driver

The Stepper motors don't rotate in the manner of a traditional motor instead, they step. Steppers make repeated movements of small, fixed increments, appearing to the naked eye as continuous motor rotation. The size of each step is determined by the motor, and the power behind these steps comes from the stepper motor driver as previously stated we are using a Arduino mega 2560 microcontroller and letting it control the stepper motor can take up a lot of the processing and not leave you a lot of room to do anything else to overcome this short coming we are using a multipurpose built stepper motor driver TB6600HG manufactured by TOSHIBA. The figure shows the Stepper Motor Diver TB6600HB.

2.3 Stepper Motor

A stepper motor, also known as step motor or stepping motor, is a brushless DC electric motor that divides a full rotation into a number of equal steps. The motor's position can then be commanded to move and hold at one of these steps without any position sensor for feedback (an open-loop controller), as long as the motor is carefully sized to the application in respect to torque and speed. Switched reluctance motors are very large stepping motors with a reduced pole count, and generally are closed-loop commutated. The type of stepper motor used in this project is a Nema 17 stepper motor which has torque is 3.2Kg.cm. with 1.8° step angle (200 steps/revolution).

Figure 2.4: Nema 17 Stepper Motor

2.4. Proximity Sensor

A proximity sensor is a sensor able to detect the presence of nearby objects without any physical contact. An inductive sensor is a device that uses the principle of electromagnetic induction to detect or measure objects. An inductor develops a magnetic field when a current flows through it; alternatively, a current will flow through a circuit containing an inductor when the magnetic field through it changes.

2.5 Switch Mode Power Supply (Smps)

The SMPS is a versatile power supply as we can choose from different topologies like Step – up (Boost), Step – down (Buck), power supplies with isolation at input and output depending on the type of application. The prime problem with batteries is the voltage is either too high or too low. Hence, an SMPS will provide a regulated DC output.

Figure 2.5: SMPS

2.4. Arduino Mega 2560

Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It is intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments.

The Arduino Mega 2560 R3 is an open source precise microcontroller board Successor to the Arduino Mega based on the ATmega2560 SMD chip. The Mega 2560 R3 also adds SDA and SCL pins next to the AREF. In addition, there are two new pins placed near the RESET pin. One is the IOREF that allow the shields to adapt to the voltage provided from the board. The other is a not connected and is reserved for future purposes.

The Mega 2560 R3 works with all existing shields but can adapt to new shields which use these additional pins.

• Arduino Mega 2560 is a microcontroller board based on Atmega2560. It comes with more memory space and I/O pins as compared to other boards available in the market.
• There are 54 digital I/O pins and 16 analog pins incorporated on the board that make this device unique and stand out from others.
• Out of 54 digital I/O, 15 are used for PWM (pulse width modulation).
• DC power jack is coupled with the board that is used to power the board.
• ICSP (In-Circuit Serial Programming) header addition to Arduino Mega which is used for programming the Arduino and uploading the code from the computer.
• This board comes with two voltage regulator i.e. 5V and 3.3V which provides the flexibility to regulate the voltage as per requirements as compared to Arduino Mini which comes with only one voltage regulator.

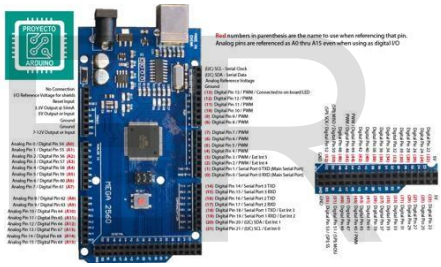

Figure 2.6: Pin layout of Arduino Mega 2560

2.6. Circuit Diagram

As we can see from the below figure circuit diagram the PUL - , DIR-, ENA-, Ground Pin of Arduino and negative terminal of SMPS are connect to same wire and DIR+, ENA+, PUL+ are connected to Arduino pins 30, 31, 32 and positive wire form SMPS is connected to VCC terminal of stepper motor driver and other terminal of SMPS are connected to the AC power supply in the same way the other 2 stepper motor divers and 2 stepper motors are connected and load the code to Arduino by connecting USB cable to computer.

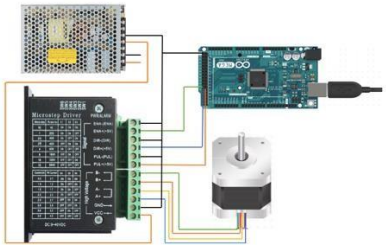

Figure 2.7: Circuit Diagram for one stepper motor connection

3. Software Description

3.1. Python

Python is a broadly utilized general-purpose high-level programming language .Its syntax structure permits the software engineers to express ideas in less lines of code, compared to different programming languages like C, C++or java.

3.2. OpenCV

OpenCV **[9]** (Open Source Computer Vision) is a library of programming capacities fundamentally used for continuous PC vision/image processing.

3.3. Numpy

Numpy is a package that characterizes a multi-dimensional Array object and related quick math works that work on it.Numpy is an augmentation to the Python programming language, including support for vast, multidimensional array and matrices, along with an extensive library of high – level mathematical capacities to work on these arrays.

3.4. Pyserial

This module encapsulates the access for the serial port . It provides backends for Python running on Windows, OSX, Linux, BSD . The module "serial automatically selects the appropriate backend. This module allows us to control the microcontroller from python which gives advantage to customize for any application

3.5. Tkinter

Tkinter is the standard GUI library for Python. Python when combined with Tkinter provides a fast and easy way to create GUI applications. Tkinter provides a powerful object-oriented interface to the Tk GUI toolkit.

3.6. Arduino IDE

A program for Arduino **[8]** hardware may be written in any programming language with compilers that produce binary machine code for the target processor. Atmel provides a development environment for their 8-bit AVR and 32-bit ARM Cortex-M based microcontrollers: AVR Studio (older) and Atmel Studio (newer)

4. Methodology

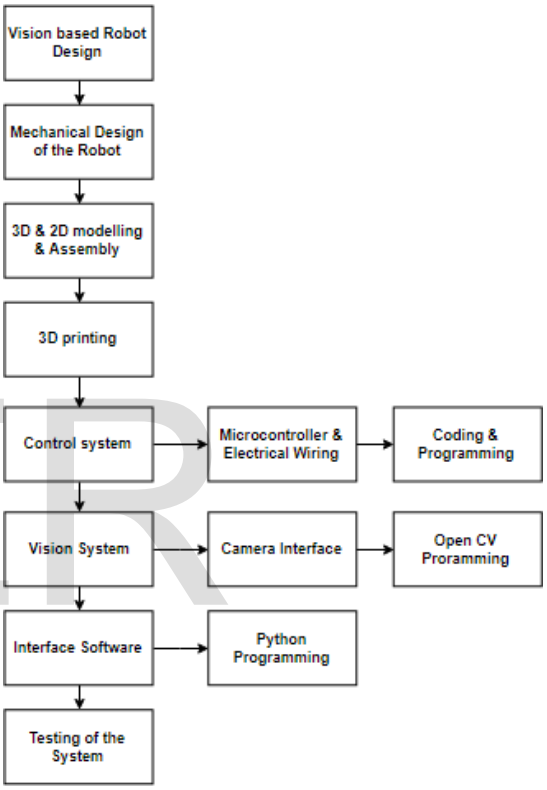

Figure 4.1 Flow Chart

The flow chart consists of a vision based robot design this method involves mechanical design of the robot, 3D & 2D modelling & assembly , 3D printing . 3D printing is done involving control systems, microcontroller & Electrical wiring , coding & programming. Control system consists of a vision system where camera interface is placed through CV programming. Python programming is done in interface software where relevant codes and programs are given to process the input. Then testing of the system is done after completion of the following methodology .

5. 3D MODELS

In the below figures we can see the 3d model of the articulated robot and robot with camera stand assembly.

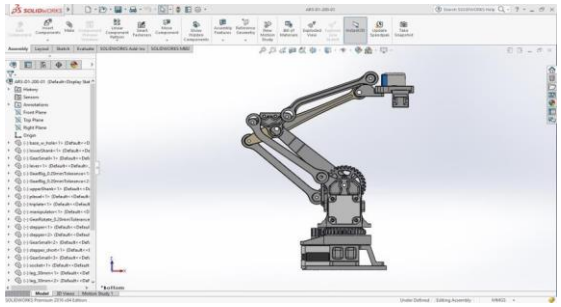

Figure 5.1: Articulated Robot

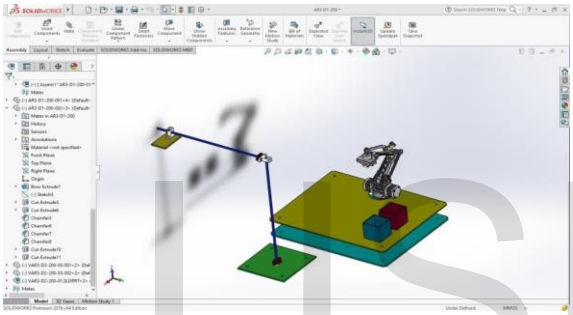

Figure 5.2: Assembly of Robot

6. Conclusions

Nowadays, the use of robots in several logistics for moving packages from one end to other end on some industries for fault detection applications with complex designs. In this work a Vision based Articulated Robot system is successfully constructed for pick and place an object from one place and sort them by their size by of 3 DOF from the 3D printer and commercially available parts. The digital image processing are implemented by python OpenCV module. In this system, the camera is used as a sensor captures the image of the object and the dimensions of the object are measured after processing the image in PC. The object dimensions are determined by the edge detection and shape detection by python and Arduino ide software tools. From the real-time test and measurement it is observed that the robotic arm requires a 4-DOF for a full-fledged working in pick and place sorting applications. So, the work can be further carried out by increasing the degrees of freedom and in the body of robot and making use of a high resolution 3D camera

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