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Robotic Four Finger ARM Controlling using Image Processing

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Abstract:
The paper presents a smart approach for a real time inspection and selection of objects in continuous flow. Image processing in today's world grabs massive attentions as it leads to possibilities of broaden application in many fields of high technology. The real challenge is how to improve existing sorting system in the modular processing system which consists of four integrated stations of identification, processing, selection and sorting with a new image processing feature. Existing sorting method uses a set of inductive, capacitive and optical sensors do differentiate object color. Here we show a straight forward technique of tracking the human hand using the robotic arm. This is about interfacing of human hand using robot arm. With this method the robotic hand can be controlled using human hand. Its demonstration is done by using image processing technique to detect different human hand gestures. This technique is very useful since it takes real time video of hand and tracks it to get interface with robotic arm. A laptop camera will get the video different human hand gestures. Tracking of such hand will interface the controller with robotic arm. The main aim behind this approach to program a robotic arm, so that it should be controlled by human hand and will reach the locations where human will not be able to reach and do the given task by direct interfacing with human hand. In this we can see the real time movement of robotic arm.

Keywords: Robotic Hand, Camera, Arduino, Laptop, Image processing software, MATLAB software

I. INTRODUCTION

Nowadays, robots are increasingly being integrated into working tasks to replace humans especially to perform the repetitive task. In general, robotics can be divided into two areas, industrial and service robotics. International Federation of Robotics (IFR) defines a service robot as a robot which operates semi- or fully autonomously to perform services useful to the wellbeing of humans and equipment, excluding manufacturing operations. These robots are currently used in many fields of applications including office, military tasks, hospital operations, dangerous environment and agriculture. Besides, it might be difficult or dangerous for humans to do some specific tasks like picking up explosive chemicals, defusing bombs or in worst case scenario to pick and place the bomb somewhere for containment and for repeated pick and place action in industries. Therefore a robot can be replaced human to do work. Robotic arms are used in lifting heavy objects and carrying out tasks that require extreme concentration and expert accuracy. This study mainly focuses on the accuracy in control mechanism of the arm while gripping and placing of objects. The system facilitates autonomous object detection within its limitations. A user interface is incorporated with the system for human input feed on the desired destination within the working frontiers. The targeted destination is specified in terms of height, radius and angle. In addition the orientation of the object can be provisioned along with the destination. Determining real time and highly accurate characteristics of small objects in a fast flowing stream would open new directions for industrial sorting processes. The present paper relates to an apparatus and method for classify in and sorting small-sized objects, using electronic systems and advanced sensors operating on the basis of a physical and geometric characterization of each element. Recent advances in electronics and printed circuit board technology open new perspectives for industrial application in this field.[1][4] .

II. HARDWARE SPECIFICATION:

1. ARDUINO:

Arduino is an open source electronics prototyping platform based on flexible, easy to use hardware and software. It's intended for artist, designers, hobbyists, and anyone interested in creating interactive object or environment as shown in fig:(2.1). The Arduino can sense the environment by receiving input from a variety of sensor and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino UNO programming language (based on wiring) and the Arduino development environment (based on processing). Arduino projects can be stand-alone or they can communicate with software running on a computer.

Figure.1. Arduino UNO R3

The board can be built by hand or purchased pre-assembled the software can be download for free.

2. WEB CAMERA:

Figure.2. Webcam

The camera used in this case will be overhead camera, it will take the snapshot of the object for color sensing purpose. The image captured by the camera will be processed by image processing using matlab. The camera used in this case is Logitech PN 960-000748 whose technical specifications are:

1. Video calling (640 x 480 pixels)
2. Video capture: Up to 1024 x 768 pixels
3. Fluid Crystal Technology
4. Photos: Up to 1.3 megapixels (software enhanced)
5. Built-in mic with noise reduction
6. Hi-Speed USB 2.0 certified (recommended)
7. Universal clip fits laptops, LCD or CRT monitors

3. ROBOTIC ARM:

Figure.3. Robotic Arm

Arms are types of jointed robot manipulator that allow robots to interact with their environment. Many have onboard controllers or translators to simplify communication, though they may be controlled directly or in any number of ways. Due to this fact, standalone arms are often classified as full robots. Axis 2 and 3 enables gripper tomaintain its angle constant with the surface while moving up and down. Robotic arm can do Left-Right, Up-Down while keeping gripper parallel to surface, Twist motions and Gripping action. Robotic Arm will require current up to 5Amps. Make sure that your robot can supply that much amount of current for proper operation of the arm.

4. SERVO MOTORS:

A servo motor consists of three major parts: a motor, control board, and potentiometer (variable resistor) connected to output shaft. The motor utilizes a set of gears to rotate the potentiometer and the output shaft at the same time. The potentiometer, which controls the angle of the servo motor, allows the control circuitry to monitor the current angle of the servo motor. The motor, through a series of gears, turns the output shaft and the potentiometer simultaneously. The potentiometer is fed into the servo control circuit and when the control circuit detects that the position is correct, it stops the servo motor. If the control circuit detects that the angle is not correct, it will turn the servo motor in the right direction until the angle is correct. Servo or RC Servo Motors are DC motors equipped with a servo mechanism for precise control of angular position. The RC servo motors usually have a rotation limit from 90° to 180°. But servos do not rotate continually. Their rotation is restricted in between the fixed angles.

Figure.4. Servo Motor

5. KINEMATICS:

Kinematics is the science of motion. In a two-joint robotic arm, given the angles of the joints, the kinematics equations give the location of the tip of the arm. Inverse kinematics refers to the reverse process, given a desired location for the tip of the robotic arm, what should the angles of the joints be so as to locate the tip of the arm at the desired location. There is usually more than one solution and can at times be a difficult problem to solve. This is a typical problem in robotics that needs to be solved to control a robotic arm to perform tasks it is designated to do. In a 2-dimensional input space, with a two-joint robotic arm and given the desired co-ordinate, the problem reduces to finding the two angles involved. The first angle is between the first arm and the ground (or whatever it is attached to). The second angle is between the first arm and the second arm.

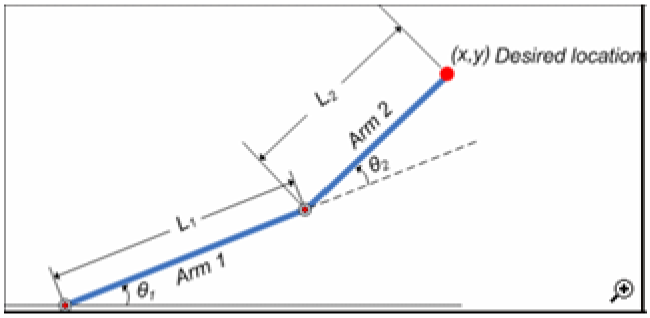

Figure.5. Illustration showing the two-joint robotic arm with the two angles

In this case the lengths of both the links are known which equal to 40cm. Therefore using forward kinematics, we can calculate the whole reachable area of the end effectors. This helps in estimating the catching area of the ball. First the reachable area of end effectors was calculated in MATLAB.

Then from that reachable area, a particular area was decided was as catching area for ball.The inverse kinematics model is implemented in code running in computer to calculate the joint angles for servo motor using the co-ordinates of ball which are obtained from image processing algorithm.

Mathematical model for forward kinematics:

X = l1 * cos (THETA1) + l2 * cos (THETA1 + THETA2); % x coordinates

Y = l1 * sin (THETA1) + l2 * sin (THETA1 + THETA2); % y coordinates

Mathematical model for inverse kinematics:

c = (X*X + Y*Y – l1*l1 - l2*l2) / (2*l1*l2);
s = sqrt (1 – c*c);
k1 = l1 + l2*c;
k2 = l2*s;
THETA1 = atan2 (Y, X) – atan2 (k2, k1); % theta1 is deduced
THETA2 = atan2(s, c); % theta2 is deduced

III. SOFTWARE SPECIFICATION:

1. MATLAB

MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment and fourth- generation programming language. A proprietary programming language developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, Fortran and Python. Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems.

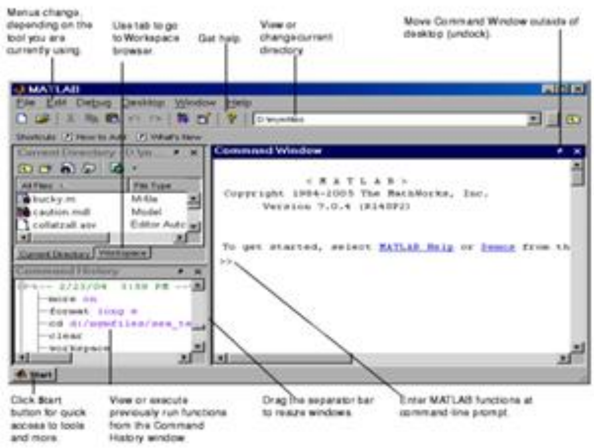

Figure.6. The graphical interface to the MATLAB workspace

2. IMAGE PROCESSING:

Predicting the ball with stereo vision camera is extremely expensive as we need Giga interface cards and more powerful programming language to interface. I therefore used a single camera system mounted on celling such that the camera feed covers entire region. This camera is connected to a computer. Computer captures the video from the camera. A program is written in C language using standard OpenCV library functions which runs in MATLAB. This program calculates the location of ball in real time. The program also calculates the joint angles of the robotic arm. These angles are sent to the controller of the robotic arm via RS-232 port at a baud rate of 115200 bps. The microcontroller used for riving the actuators is arduino which runs at clock frequency of 14745600 Hz. The robotic arm is fabricated using lightweight aluminum strips. The actuators used are servo motor (15kg.cm) for precise angle control and angular speed. A TSOP based obstacle sensor is also mounted at end effector to check whether the end effector is reached up to ball or not.

IV. ALGORITHM:

1. TRACKING ALGORITHM:

Three basic steps in tracking are:
step1: Approximation of foreground data α
step2: Background data estimation
step3: Next probable position can be obtained through mean shift algorithm

2. IMAGE PROCESSING ALGORITHM:

Step 1: Start
Step 2: Start Video
Step 3: Get snapshot from video.
Step 4: Resize the image.
Step 5: Save the image temporarily.
Step 6: Read image from the file and extract information of the image.
Step 7: Get the red, green, blue matrices.
Step 8: Displaying the subplots of red, blue, green components of the images.
Step 9: Initiate the loop for finding maximum value of the matrices.
Step 10: Print red if red component is greater. Print green if green component is greater. Else print blue.
Step 11: Send command to the ARDUINO board from MATLAB serially
Step 12: The microcontroller receives the commands.
Step 13: According to the command from microcontroller the robotic arm will pick the object then came back to the normal position.
Step 14: Based on the color the arm will place the object in desired position.
Step 15: Go to step1

V. EXPERIMENTAL PROCESS:

In this, process is about interfacing of human hand using robot arm. With this method the robotic hand can be controlled using human hand. Demonstration is done by using image processing technique to detect different human hand gestures. Technique is very useful since it takes real time video of hand and tracks it to get interface with robotic arm. The image of hand is captured by webcam which is interfaced with MATLAB software. In MATLAB were performing image processing. The captured image of hand is processed and gesture is obtained. For each gestures of d image obtained from That image is transmitted as serial data through USB of laptop to the USB module attached with ARDUNIO. Were the USB interfaced with ARDUNIO board will control the action of the robot arm. The data's transmitted from USB be serial format and receiving will be also in serial form

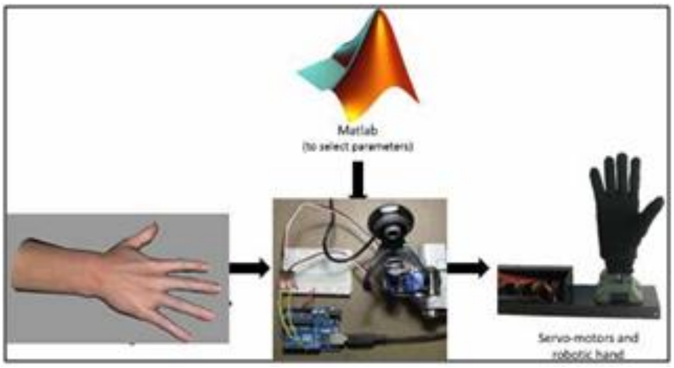

Figure.7. processes diagram

The project uses a single camera system for the purpose of image processing. A camera is mounted on celling such that the camera feed covers whole region. This video feed is captured in the computer. A program is written in C language to detect the location of ball in real time and predict the trajectory of the ball. The program also calculates the angle required to send to servo motors using mathematical model for inverse kinematics. The program is written in C language using standard Open CV functions. Open CV (Open Computer Vision) is a library that implements many algorithms commonly used in the field of computer vision. Computer vision is the area of computer science that focuses on extracting structured information from images. Images as they are stored on computers are large, unstructured, two dimensional arrays of pixels. Computer vision techniques can also be applied to videos, which are stored as sequences of images. Open CV provides algorithms that can be used for tasks such as locating faces in an image, recognizing predefined objects and shapes and detecting movement in a video. Open CV also provides the infrastructure necessary for working with images and videos. The steps involved in the image processing algorithm are:

1. VIDEO CAPTURE:

The very first task in image processing algorithm is to get the actual vide feed from camera. The starts to capture the video frame by frame, afterwards these frames are used in order to do apply further image processing algorithm.

2. SETTING REGION OF INTEREST:

It is not always necessary to process the whole image which we get from camera. It advisable to process the required part of image only as it reduces the processing time. So for that I have used some track bars to define the region of interest which we have to set before further processing.

3. CALIBRATION FOR COLOR DETECTION:

After setting the ROI, the next task is to do the calibration for detecting the color. The BGR image is first converted to HSV colorspace. Every fixel is checked for its value of hue, saturation and intensity. A lower and and upper limit is set for these three during calibration. After calibration if value of pixel lies in that range then that pixel is set white, otherwise black. In this way color detection is done and a BGR image is converted in a binary image which is further processing after calibration.

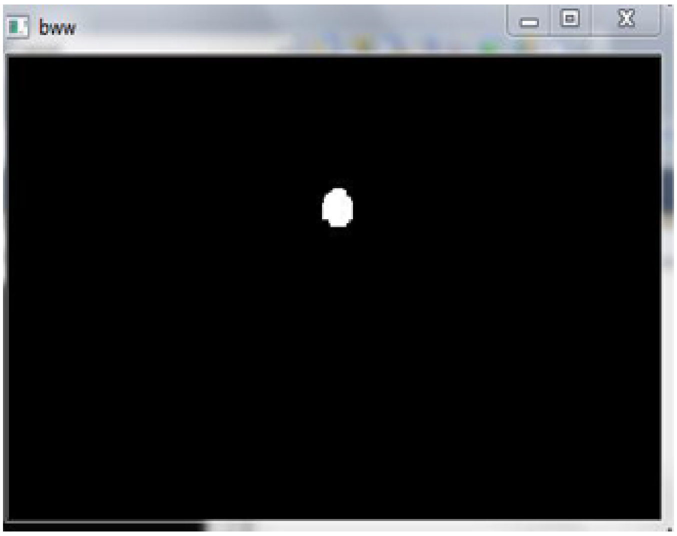

Figure.8. Binary image (Color detection)

4. OBJECT TRACKING:

Now after calibration, the binary image is directly accessed. The white patch in binary image indicates the colored ball. The centroid of ball is computed in each frame using OpenCV functions. In this way trajectory of ball is determined.

5. INVERSE KINEMATICS MODEL:

As the centroid of the ball is computed, we have the x and y co-ordinates of ball in the plane. Now using mathematical model for inverse kinematics, the joint angles for servo motors are calculated. **Serial communication:** Once we get the joint angles, the only job remained is to send these angles to microcontroller. These angle are sent to microcontroller by accessing the serial port of computer via RS232 port at a baudrate of 115200 bps.

VI. APPLICATIONS

The robots find numerous applications in industrial, domestic, medical, pharmaceutical and hazardous environment where human life is at risk. Some major applications are:

1) **Industry:** object sorting arm can be used in manufacturing industries to sort the objects based on fault like missing or mistaken drill holes, dimensions, weight etc.

2) **Medical:** robotic arm ae used in tele surgery and also helpful for accurate surgeries.

3) **Defense:** Robotic arm can be used to diffuse the bombs.

4) **Hazardous environments**: robotic arm can be used in environment such as coal mines, radiation places which is either perilous or dangerous to access.

5)**Space robot**: Robotic arm can be used in space examination programs.

VII. RESULT

Through the review of the above papers, industrial models and books on robotic hands and their control, we can say that the field of robotics especially in mimicking human motions is growing and expanding rapidly. The various artificial models discussed above show differences in the number of fingers, the number of degrees of freedom, the methodology of control, the interface and ways of tracking hand movement. On an overall basis, majority of the models have a sensory glove, Cyber glove or force feedback glove that are worn on human hands to monitor and record the human hand movements. The robotic end effectors are generally five fingered and each model has some extra added feature like pressure sensing, tactile sensing, twist drive feature etc. Mostly the arduino is used for processing the sensor information into the control signals for actuators, while the communication is established either through Ethernet, Bluetooth or RF communication. hand gesture recognition using image processing was also used. In spite of all the advancement and expertise in this area, still the problem of efficiency, size, weight and speed of interaction between master and slave need to be improved, to be able to suit for real time dynamically changing environment. The future scope pertains to applying slight modifications to overcome these problems. By using servos, modelling using, Arm control using image processing and long distance communication using high speed internet protocol, a better model can be developed which minimises or removes the before mentioned drawbacks. With the field of networking ever developing, the current internet protocol IPV4 in combination with IPV6 protocol can be used for long distance tale-operation.[7] The reflexivity and fast control of robotic hands with human hands can be done with high precision using advanced tools for image processing like MatLab, OpenCV etc., to capture and track human hand movements. With the use of micro servos, the required torque can be achieved with minimum weight and size, to make the robotic hand lighter and more like real hand. modelling provides the flexibility, strength and real hand like look

POSSIBLE IMPROVEMENTS:

1. Current prototype is not sufficiently big to cover larger area, so this can be rectified by using longer links provided we have good actuators to drive them.
2. Using better actuators other than servo motor as servo motors have limited angular
rotation and it very difficult to find a high torque servo motor with good performance and speed.
3.Links can be fabricated using some other material which is sturdy enough and light in weight.
4.The current prototype shows some performance issues while the ball is continuously moving. Actually the end effector many times lags behind the ball, some good solution to rectify this.
5.The current image processing algorithm can modified to predict the future trajectory of ball.
6.Same methodology can be implemented on the basis of shape detection algorithm. The robot can be used as an object sorting robot on basis of color and shape. Also the degrees of freedom can be increased for utilizing this concept in 3-D region.

VIII. FUTURE SCOPE:

These robotic hands can be used in prosthesis as prosthetic hands, attached over the handicapped hand and by analysing the nerve pulses from the cut arm; the artificial hand can be controlled to function as the human hand which is the scope of future.

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