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Miss Jayashree Arun Ahire

Abstract

Quality of life of individuals suffering with movement disorders can be improved using assistive robotic devices. Robotic arm can help people with upper body mobility to perform daily tasks. Controlling robotic arm manually can be challenging for wheelchair users with upper extremity disorders. An autonomous wheelchair mounted robotic arm is built using a computer vision interface. It consists of: a robotic arm with six degrees of freedom, an electric wheelchair, computer system and two vision sensors. The first vision sensor detects the coarse position of the coloured objects placed randomly on a shelf placed in front of the wheelchair using a computer vision algorithm. Another vision sensor ensures correct position of object in front of the gripper and thus, provides fine localization. The arm is then controlled automatically to pick up the object and return it to the user. Performance of the robotic arm is evaluated after conducting tests by placing objects at different locations. The tasks are completed under one minute. Experiments are done to implement a camera based vision system integrated with a computer vision algorithm to recognize object deformation and spatial coordination to control the deviation from the original training. The visualization systems are able to detect the objects as well as their distance from the End-effecter and transmit the signals to the drive system.

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Chapter 1

Introduction

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. Service robot is an operational aid 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.

1.1 Robotic Arms

The most common manufacturing robot is the robotic arm. A typical robotic arm is made up of seven metal segments, joined by six joints. The computer controls the robot by rotating individual step motors connected to each joint (some larger arms use hydraulics or pneumatics). Unlike ordinary motors, step motors move in exact increments. This allows the computer to move the arm very precisely, repeating exactly the same movement over and over again. The robot uses motion sensors to make sure it moves just the right amount. An industrial robot with six joints closely resembles a human arm – it has the equivalent of a shoulder, an elbow and a wrist. Typically, the shoulder is mounted to a stationary base structure rather than to a movable body. This type of robot has six degrees of freedom, meaning it can pivot in six different ways. A human arm, by comparison, has seven degrees of freedom.

Robotic hands often have built-in pressure sensors that tell the computer how hard the robot is gripping a particular object. This keeps the robot from dropping or breaking whatever it's carrying. Other end effectors include blowtorches, drills and spray painters.Industrial robots are designed to do exactly the same thing, in a controlled environment, over and over again. For example, a robot might twist the caps onto peanut butter jars coming down an assembly line. To teach a robot how to do its job, the programmer guides the arm through the motions using a handheld controller. The robot stores the exact sequence of movements in its memory, and does it again and again every time a new unit comes down the assembly line. While there are other robot arms that have been helping humans for years behind the scenes, medical robotic arms are breakthroughs that could help many paralyzed and amputation patients in the future.

Robotic arms perform many tasks for human workers like pick and place, palletizing and other material handling applications that can be dull and injury-inducing. They also perform tasks like welding and material removal that produce fumes and particles that can be hazardous to humans.

1.2 Computer Vision

Humans use their eyes and their brains to see and visually sense the world around them. Computer vision is the science that aims to give a similar, if not better, capability to a machine or computer.

Computer vision is a field that refers to the methods of acquiring, processing, analyzing, and understanding images. Computer vision is concerned with the extraction of information from images. The image data can take many forms, such as video sequences, views from multiple cameras, or multi-dimensional data. Computer vision encompasses scene reconstruction, event detection, video tracking, object recognition, object pose estimation, learning, indexing, motion estimation, and image restoration. Several tasks relate to motion estimation where an image sequence is processed to produce an estimate of the parameters either at each points in the image or in the 3D scene, or even of the camera that produces the images. Examples of such tasks are: Ego motion, Tracking and Optical flow. Computer Vision can be implemented using embedded systems to task specific efficient systems.

1.3 Robotic Arms helping people with physical disorders

Robotic arms mounted on a wheel chair largely benefit people suffering from upper body movement disorders such as Amyotrophic Lateral Sclerosis (ALS), Parkinson's disease, Progressive Muscular Atrophy (PMA)[1]. They can enhance the manipulation capabilities for electric wheelchair users and make them feel more independent. But wheelchair mounted robotic arms (WMRA) available in the market such as JACO Robot arm by Kinova Robotics and iARM by Assistive Innovations utilize remote controlled interface such as joystick to control the arm. This might be challenging to operate for users suffering from motor neuron diseases and in many cases it can consume a lot of time and effort to successfully grasp the object. They are also very expensive usually run into thousands of dollars.

Chapter 2

Literature Survey

2.1 Kinova Robotic arm

The humans we seek to empower are as diverse as they come. Kinova's range of technologies provide support to individuals affected by a vast array of conditions (ALS, cerebral palsy, multiple sclerosis, muscular dystrophy, rheumatism, spinal muscular atrophy, stroke, tetraplegia) and injuries (general back and shoulder pain, repetitive strain, spinal cord injuries), as well as natural deterioration due to aging. Regardless of whether you're old or young, female or male, or the degree to which you require assistance, our solutions are adaptable to your situation and your environment.

Users will achieve a newfound sense of autonomy and an improved quality of life. Our solutions can help maximize your abilities and decrease thier reliance on family members and care workers, letting them function at a higher level both at home and in society. Activities of daily living (eating, drinking, grooming, manipulating objects) will feel easier and a greater sense of purpose will be established in your daily life. It's a wonderful feeling to know that new things are suddenly possible and to tackle new challenges.

Various methods of operating the arm are as follows:

2.1.1 Integrated vision-based robotic arm interface

Previous studies have been conducted to develop wheelchair-mounted robotic manipulators (WMRMs) that provide persons with upper extremity mobility impairments, such as persons with upper-level SCIs, greater autonomy and less reliance on others in retrieving and manipulating objects for activities of daily living (ADL)[2]. The development of WMRMs has been facilitated by the availability of commercial robotic arms emerging in the market. For instance, the Manus manipulator, produced by Exact Dynamics is a 6 degree of freedom (DoF) robotic manipulator that can be re-programmed and mounted to a wheelchair system. The JACO robotic arm developed by Kinova is a light-weight robotic manipulator that is designed to be mounted to a motorized wheelchair to help people with upper limb impairments with ADL. However, these commercially-available systems are designed to be controlled by traditional modalities (i.e. joystick), which may not be usable by operators with upper extremity motor impairments.

Prior investigations in human-computer interaction (HCI) for persons with upper extremity motor impairments or quadriplegics has resulted in alternate user input options. The greatest advances have occurred in personal computer (PC) control utilizing speech recognition, facial expression, eye tracking, and hand gesture recognition. However, these HCI modalities, which do not rely upon switch or joystick operation, have also been useful for controlling actuated assistive technology (AT) devices, such as driving intelligent wheelchairs. Alternate input modalities that do not require switch, button or joystick operation for directly or semi autonomously controlling intelligent wheelchairs include speech recognition, gesture recognition, tongue movement, or electromyography (EMG) and electrooculography (EOG).

2.1.2 Machine Vision-Based Gestural Interface

A machine vision-based gestural interface was developed to provide individuals with upper extremity physical impairments an alternative way to perform laboratory tasks that require physical manipulation of components. A xcolor and depth based 3-D particle filter framework was constructed with unique descriptive features for face and hands representation. This framework was integrated into an interaction model utilizing spatial and motion information to deal efficiently with occlusions and its negative effects. More specifically, the suggested method proposed solves the false merging and false labeling problems characteristic in tracking through occlusion. The same feature encoding technique was subsequently used to detect, track and recognize users' hands[3]. Experimental results demonstrated that the proposed approach was superior to other state-of-theart tracking algorithms when interaction was present (97.52% accuracy).

For gesture encoding, dynamic motion models were created employing the dynamic time warping method. The gestures were classified using a conditional density propagationbased trajectory recognition method. The hand trajectories were classified into different classes (commands) with a recognition accuracy of 95.9%. In addition, the new approach was validated with the "one shot learning" paradigm with comparable results to those reported in 2012. In a validation experiment, the gestures were used to control a mobile service robot and a robotic arm in a laboratory chemistry experiment[3]. Effective control policies were selected to achieve optimal performance for the presented gestural control system through comparrison of task completion time between different control modes.

2.1.3 3D joystick for robotic arm control

Recent advancement in computers and robotics makes it possible for people with spinal cord injuries (SCIs)[5] and other upper limb mobility impairments to perform daily living and other tasks more independently through the assistance of a robotic arm [1]. However, operation of robotic arms has always been challenging, particularly for individuals with upper limb extremity mobility impairments. Two great challenges are faced by persons with SCI to efficiently control robotic arms. One is that the traditional manual user controllers for robotic arms require fine motor skills, which is extremely difficult for this group of users, or very technically complex, such as eyetracking, speech control, and brain-computer interfaces (BCI).

The other challenge is that each potential user has their own motor skill abilities and preferences even when comparing individuals with the same level of SCI. Therefore, the type of user interface is very individualized and may require significant customization to accommodate each subject.

Some kind of human-computer interface (HCI) must be employed to initiate and orchestrate the task. Multiple methods have been suggested to manipulate a robotic arm with sufficient dexterity to accomplish most basic tasks, such as picking up items, drinking from a glass or self-feeding. However, there are very few HCI methods that are designed specifically to facilitate individuals with upper extremity mobility impairments.

2.1.4 Brain Computer Interface for grasping using a wheelchair-mounted robotic arm

In this paper, we present a novel vision based interface for selecting an object using a Brain Computer Interface (BCI)[4], and grasping it using a robotic arm mounted to a powered wheelchair. As issuing commands through BCI is slow, this system was designed to allow a user to perform a complete task using the robotic system via the BCI issuing as few commands as possible, without losing concentration on the stimuli or the task. A scene image is captured by a camera mounted on the wheelchair, from which a dynamically sized non-uniform stimulus grid is created using edge information. Dynamically sized grids improve object selection efficiency. Oddball paradigm and P300 event related potentials (ERP) are used to select stimuli, the stimuli being each cell in the grid. Once selected, object segmentation and matching is used to identify the object. Then the user, using BCI, chooses an action to be performed on the object via the wheelchair mounted robotic arm (WMRA). Tests on 6 healthy human subjects validated the functionality of the system. An average accuracy of 85.56% was achieved for stimuli selection over all subjects. With the proposed system, it took the users an average of 5 commands to grasp an object. The system will eventually be useful for completely paralyzed or locked-in patients for performing activities of daily living (ADL) tasks.

Chapter 3

Proposed System

3.1 Problem Definition

Existing technologies utilize heavy remote controlled interfaces such as joystick, Human Computer Interaction (HCI) or Brain Computer Interaction (BCI) to control the arm. This might be challenging to operate for users suffering from motor neuron diseases and in many cases it consumes lot of time and efforts to successfully grasp the object. They are also very expensive usually run into thousands of dollars. The proposed system can be developed with very less expenses compared to those.

3.2 System Architecture

As shown in figure 3.1, system consists of a robotic arm with six degrees of freedom, an electric wheelchair, a computer system and two vision sensors. The left arm of wheelchair has the arm mounted on it. One of the vision sensors is static. It is placed above the robotic arm and captures video of the object kept in front of it. In order to deliver accurate results, the relative distance between the sensor and the base of the arm is known prior to the start of the experiment. The shelf is used so as to achieve the goal of accessing objects at different heights. Other vision sensor is dynamic and its position can

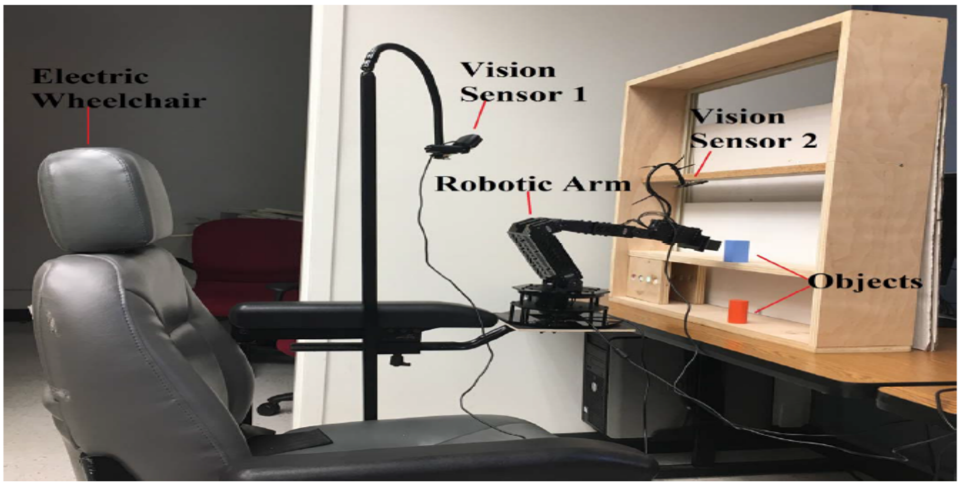

Figure 3.1: Image of the robotic arm mounted on an electric wheelchair

be varied depending on the position of the target object. For fine tuning of position of arm's gripper, another vision sensor is mounted above the gripper. It scans the position of the object before it is picked. A computer vision based system has been developed to detect multiple colored objects which lie in the specific range of the arm.The system can be divided into three parts:

3.2.1 Robotic Arm

In Fig. 3.2, A Trossen Robotics PhantomX Reactor Robot Arm is built using an Arduino compatible advanced microcontroller called Arbotix-M robocontroller[1]. The arm has eight AX-12A dynamixel actuators for controlling different parts of the arm. Each servo has sensors to track its speed, temperature, shaft position, voltage and load. The servo motor at the bottom is used to move the arm in the horizontal direction (left and right). The shoulder has dual servo which moves the arm in the forward and backward direction. The elbow also has dual servo which controls the up and down movement of the arm. The wrist angle and wrist rotate have one servo each. The arm

Figure 3.2: PhantomX Reactor Robot Arm developed by Trossen Labs

has a parallel gripper controlled by an AX-12 servo which can hold and release the object. The arm is powered by a 12V 5amp power supply and is connected to a computer system via a FTDI cable. A serial connection is made between the computer system and the robotic arm in order to communicate with the robotic arm. This was achieved by using PySerial, a python serial port access library. The serial connection has a baud rate of 38400. The data packet which is 17-byte long was sent serially from the computer to the Arbotix-M robocontroller to control the movement of the arm. The 17-byte data packet includes the header (0xFF/255), X-axis coordinate, Y-axis coordinate, Z-axis coordinate, wrist angle, wrist rotate, gripper, delta byte and check sum. Each of the servo motor can be controlled by varying the 17-byte data sent to the arm accordingly. A short delay is introduced after every serial write command is performed to ensure the reception of the 17-byte data by the robotic arm.

3.2.2 Vision Sensors

Two vision sensors (USB webcams) are used to perform object detection. A Logitech HD c920 webcam (vision sensor 1) is mounted above the robotic arm which faces the shelf located in front of the arm. It captures the video of the arm and the shelf in real time. By extracting frames from this video, they're processed and the position (X,

Y) of the target object is calculated. The data thus obtained is used for coarse positioning of the robotic arm. A robot VGA webcam (vision sensor 2) is mounted above the gripper using a 200 mm gooseneck. The vision sensor 2 captures a close-up video of the target object. Frames from this camera are captured only when the arm is moved to the position indicated by vision sensor 1. The vision sensor 2 is used to position the gripper exactly in front of the object so that the object can be picked up in a correct manner. The resolution of the images in both the camera is 640 x 480 Pixels.

3.2.3 Computer Vision Algorithm

Programming of the robotic arm is done so that it moves towards the position of a specific colored object. The color detection algorithm is written in Python using the OpenCV library[1]. The real time video of the arm and object is captured by the vision sensor which extracts the colored object from the frame being processed by the series of the steps. Each frame is converted from BGR (Blue Green Red) image to HSV (Hue, Saturation and Value) image. A specific color is filtered by applying a lower and upper limit threshold to the HSV image. Different colors have different range of hue values. Hence by providing the appropriate range of hue values, different colors can be detected simultaneously. The experiment is performed with blue color chosen as the object of interest. The resulting image is eroded to remove the noise present in the image and dilated to fill the gaps in the image. The threshold image is scanned to check the presence of contours. In case a contour is located the position of the contour is found by calculating moments. A minimum enclosing circle is drawn around the object and the center of the circle corresponds to the X and Y coordinates of the position of the object. The color detection algorithm is extended to capture data from two vision sensors and combined with the robotic arm control code to perform the desired task. Figure 3.5 shows the flowchart implementation of the computer vision algorithm.

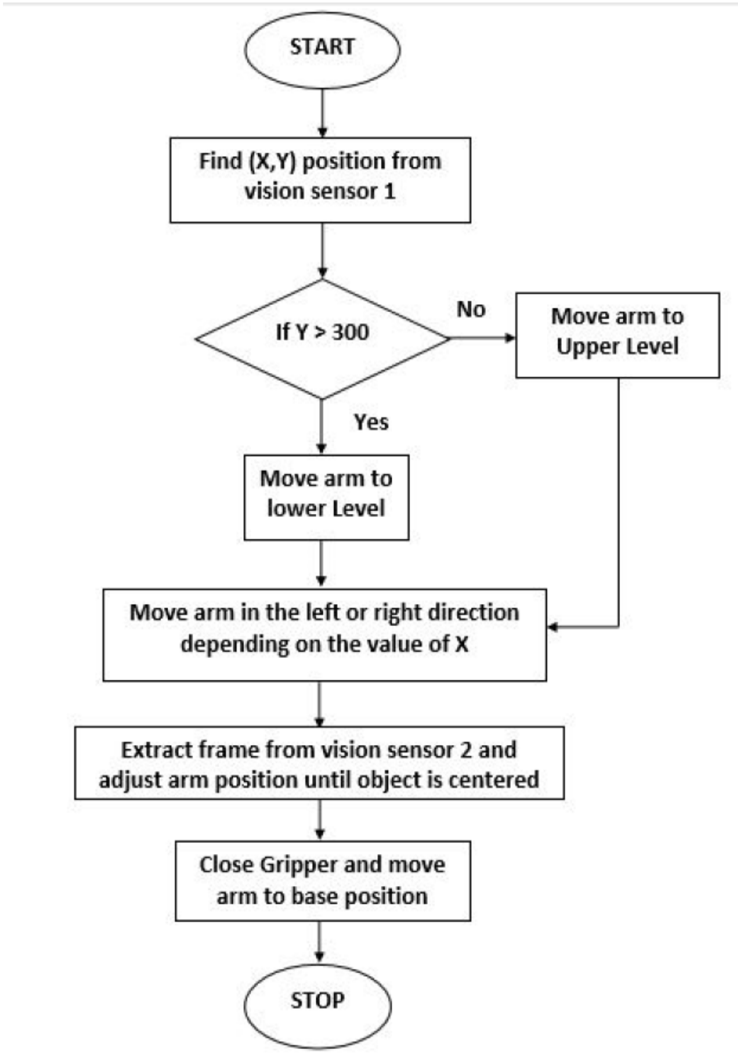

Figure 3.3: Flowchart for Robotic Arm Control

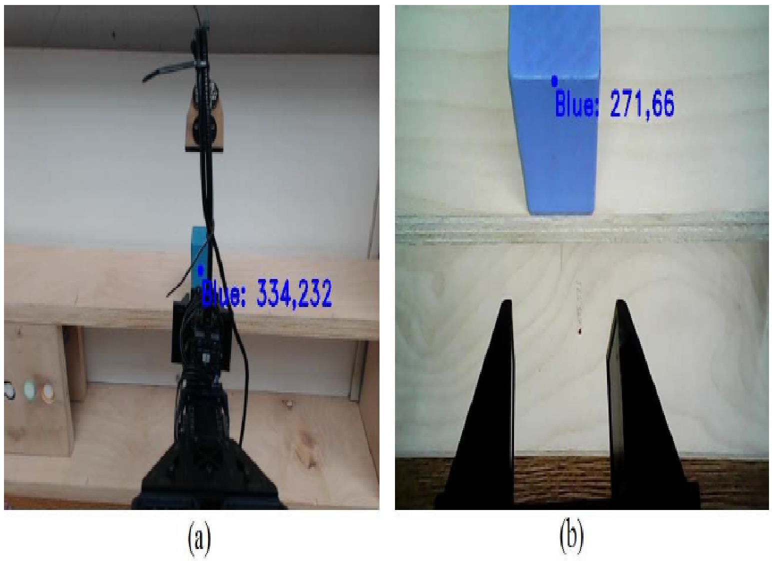

Figure 3.4: (a) Image captured by the vision sensor 1 (b) Image captured by the vision sensor 2

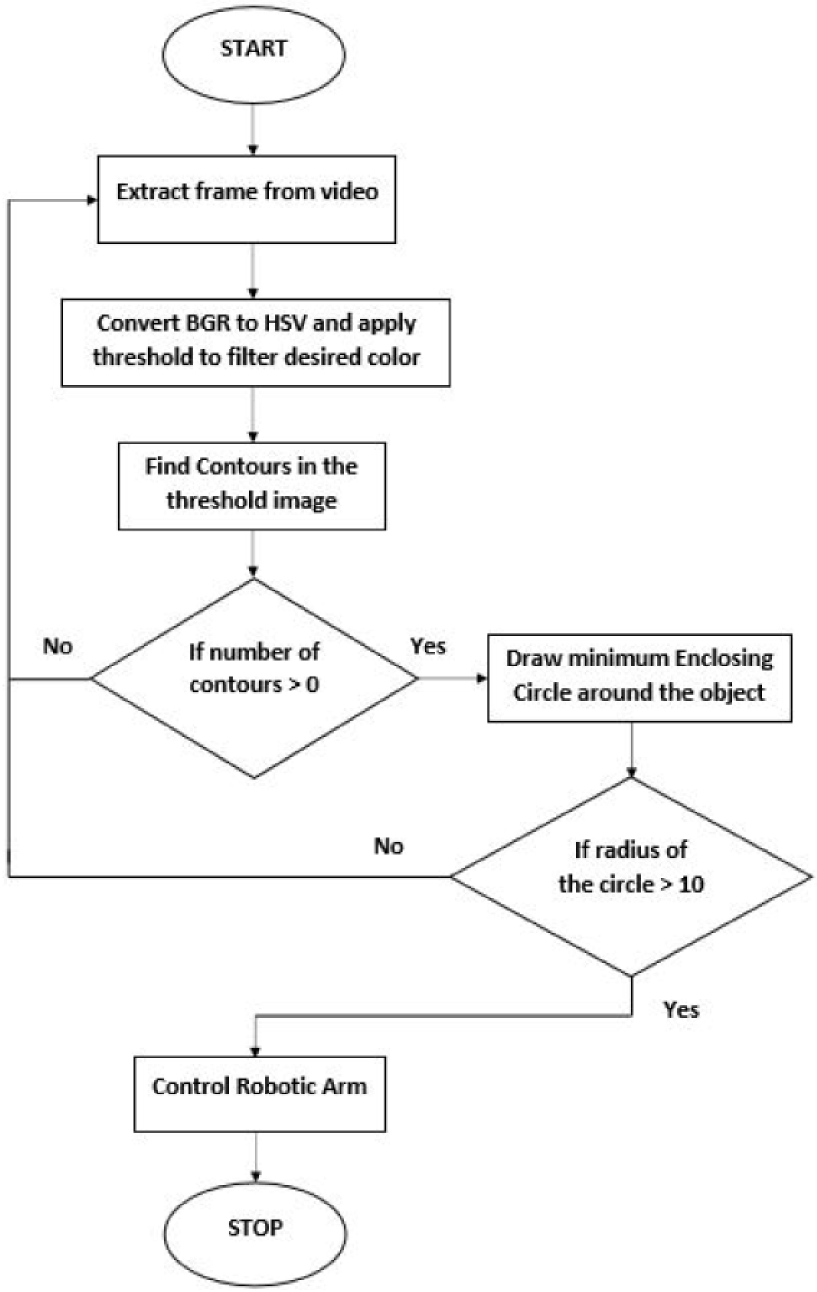

Figure 3.5: Flowchart for Computer Vision Algorithm

Chapter 4

Conclusion

A computer vision algorithm based on color detection has been developed to automate the movement of the robotic arm. This was implemented by using two vision sensors to accurately find the location of the target object. First sensor was used for obtaining the coarse location of the object and the second one was used for fine localization. The robotic arm has the ability to pick up objects placed at different locations on the upper and lower level with a success rate of 83.33%. The main goal of performing the action of picking up the object under one minute is achieved.

Color based object detection was used to determine the position of the desired object. Practical applications will involve objects of various shapes and multiple colors. A user interface can be developed that can allow the user to select a desired object from the frame captured by the vision sensor by incorporating speech recognition. Once the object selection is made, the coordinates of the object can be fed to the arm. Depth sensors can be used in addition to vision sensors to increase the performance of the robotic arm control thereby minimizing the number of unsuccessful attempts. Advanced vision algorithms can be used for pose estimation and size detection to detect same object at different angles. Incorporating the techniques mentioned above will help with detection of daily living objects and assist wheelchair users to perform tasks in a short period of time.

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