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Design of A Miniature Humanoid and Perception of Objects In Space-An Effective Method of Object Localisation

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ABSTRACT

This is an autonomous robot whose main function is to perform basic tasks such as pick and place desired objects aided by computer vision and involving hand-eye coordination. It features a smart shoulder joint design whose yaw and roll movement designs are inspired by a human shoulder joint. For perception of depth and space, the robot uses an ultrasonic distance sensor in combination with a single camera.
Keywords: Humanoid; machine vision; kinematics; inverse kinematics; object detection; joint design;

I. INTRODUCTION

This is a preliminary attempt at mimicking basic human reflexes to perform simple tasks. The main functionality of the robot is to identify objects in its target location, grab and move the object to a specific drop location, while navigating through obstacles to replicate real world conditions like those found in workplaces, homes, hospitals and other such environments, with minimal human intervention. The robot identifies objects and uses a marker based hand-eye coordination technique to grab objects. The programming and hardware could potentially be made open source to allow them to evolve and advance. The hardware is 3D printed on an FDM printer and part of the software is developed in java. The control, GUI, and image processing run on a computer, and the necessary data is transferred between the robot and the computer to avoid excessive on-board hardware.

II. DESIGN

The designed is mainly aimed at mimicking human degree of movement especially the shoulder joint, to allow greater flexibility than conventional robotic joints. Mechanical parts are 3D printed with a polymer, poly-lactic acid (PLA), which has relatively low density and has suitable strength to hold the entire weight of robot. The design is such that the material used is less but at the same time, maintains structural integrity, and balance.

A. Arms

The lower arm portion consists of a 2DOF gripper with an wrist joint and an elbow joint. The upper arm however, has a 3DOF shoulder joint that resembles a human shoulder joint. The Yaw and Roll movement is controlled by two servo motors at the top. The rotation of these servo motors actuates the two push rods (shown in blue in the Figure 4). These pushrods are printed in high infill density. The calculated movements of the 2 servo motors accounts for Adduction and abduction (Figure 3), as well as circumduction/rotation.

The 3rd servo motor attached horizontally to the base of the 2 prior motors, is responsible for the rotation of the joint along its Pitch axis (Fig 5). The rod that passes through the pitch axis is affixed to a gear (smaller gear Figure 2), and is able to rotate freely with respect to the shoulder joint. The rotation of the pitch servo causes rotation of the entire shoulder joint structure with respect to the stationary, smaller gear and the rod. The gear ratio of the 2 gears is 2:3.

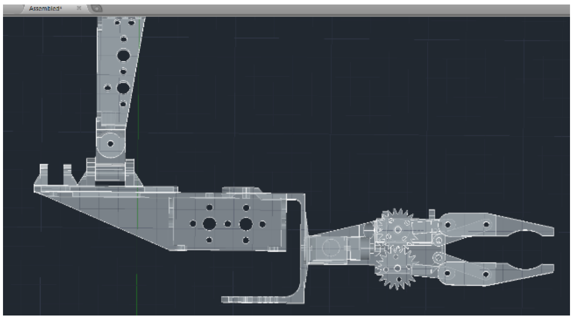

Figure 1. Arm CAD design

Thus, a 180'degree rotation of the servo causes a 270'degree rotation of the arm, much like the freedom seen in a human shoulder joint. The Smaller (stationary gear) is made thick to provide its functionality to both arms. The middle gear/neck structure is printed in high infill density and is provided with support structures since this structure bears the load of both arms.

Figure. 2 Right Arm. **Figure 3.** Adduction/Abduction

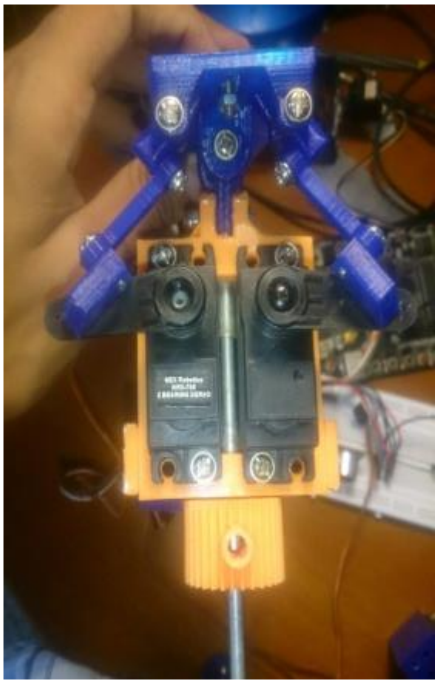

Figure 4. Shoulder top view

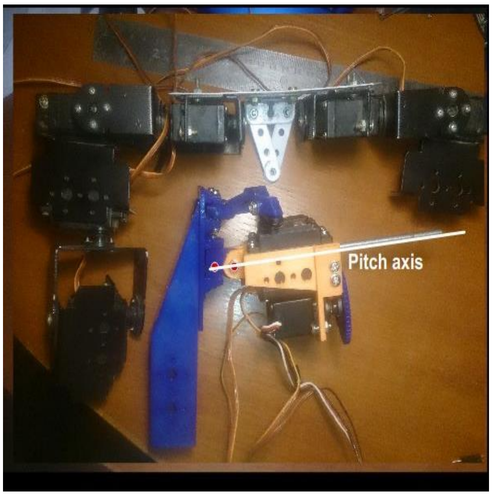

Figure 5. Pitch axis rotation

B. Head

The head consists of a 2DOF pan and tilt structure which will provide movement for the camera. The pan servo (9g micro servo) is accommodated in between the arms and a transmission rod connects the servo head to the tilt stricture above. This is done so as to reduce the total height contributed by the pan servo had it been placed over the neck. The ultrasonic distance sensor is placed above the camera over the pan/tilt mechanism.

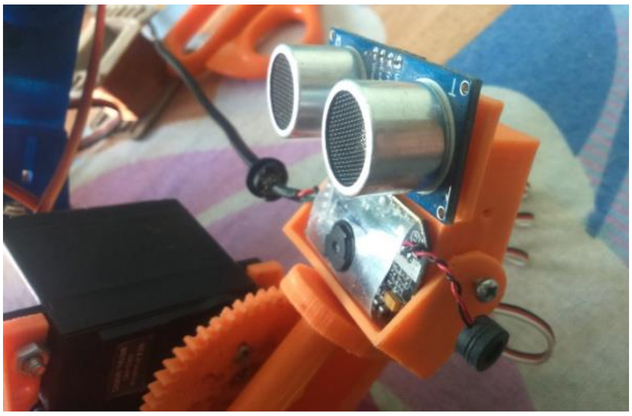

Figure 6. Ultrasonic sensor, camera

C. Lower torso and lower body design

The lower torso houses the electronics/ battery and other peripherals. As for the lower body design, a rigid longitudinal structure with wheels gives the robot very limited flexibility. Therefore, this design can provide greater flexibility of upper body movement. Three servo motors are used for this portion of the robot. This allows the robot to reach objects that are at different heights or farther away on the platform, by leaning or adjusting the height of the hips. With geometrical calculations the XZ position of the hips is adjusted through simple inverse kinematics operations.

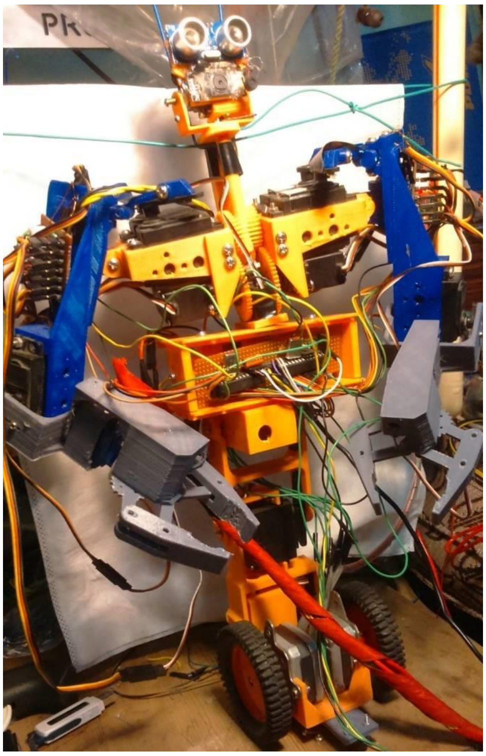

Figure 7. Assembled robot with servo motors and sensors attached

III. CONTROL AND SOFTWARE

The robot is commanded by a java program executed on a laptop. The necessary data like servo angles, sensor data, and video feed from the robot, are transferred to/from the robot and is processed by the laptop. The program is developed in Intellij Idea IDE. Image processing is done by the OpenCV package on java. The GUI is developed using the javaFX package. The microcontrollers will be having a minimum volume of code wherein it takes the angle data from the java program through the serial port, and sets the servo motors to the specified angles. Two microcontrollers control servo motors, Stepper motors for the wheels, derives input from sensors, and relates to other devices, constitutes the electronics of the robot. The microcontrollers serve as an intermediate between the java code running on a laptop/desktop, and the robot. While one microcontroller provides PWM signals for the servo motors in its arms, the other controls the rest of the constituting servo motors, sensors, and other devices. Synchronization between the two microcontrollers is done through asynchronous serial communication. The transfer of data between the computer and the two microcontrollers flows in one direction.

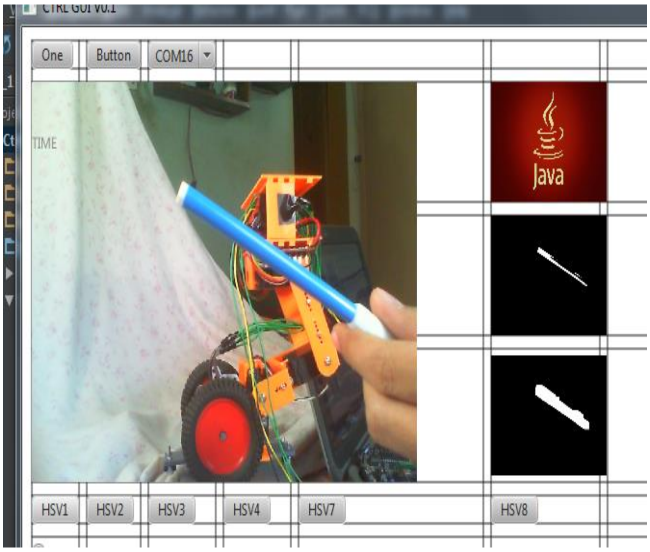

Figure 8. Identification of blue objects

The TX of the computer is connected to RX of the first microcontroller, TX of first to RX of second microcontroller, and the TX of the second back to the RX of computer. This arrangement is done so as to avoid multiple serial terminals in any of these three devices, since the latter might cause the servo motors to twitch as they are timer driven. Baud rate of 115200bps is set for maximum transfer rate. Information such as servo angles is encoded with the servo IDs before it is transferred from the computer to the robot. Sensor data (such as the ultrasonic sensor) follows the same pattern.

The java program receives video feed from the camera, and sensor data from the robot simultaneously. Separate threads are allotted for incoming and outgoing data as well as the inverse kinematics operations and other peripheral processing like GUI. These threads are synchronized via volatile variables. The robot can navigate to the location with the help of the two independently controlled wheels, and identifies the object by image processing, and with the help of the ultrasonic sensor, the robot estimates its relative distance. The object of interest is cantered in the robot's video feed by using the pan and tilt servos.

Figure 9. Blue objects and orange markers detection.

With this information (2 pan/tilt angles and distance measured by the ultrasonic sensor), the object's location relative to the sensor is calculated. The upper body is adjusted using the 3 servo motors, so that the object is in its arms reach. The relative coordinates thus obtained is translated to a coordinate system wherein the shoulder are the origin points so that inverse kinematics can be performed on these variables, to generate servo motor angles, required to grab the object. These object coordinates are further corrected using the vision system. A marker attached to one of the claws of the gripper is also being tracked along with the object of interest on separate thread. Adjustments are made to the coordinates of the arm such that the marker is brought closest to the object, before the robot engages the gripper to grab hold of the object. Figure 9 shows the filtering operation being performed to extract blue objects. Figure 9 shows the blue object (on the left image view) and the orange marker (on the right image view) being tracked.

IV. CONCLUSION

The robot can segment a specific colored object, localize it in its field of view, and estimate the object's coordinates using motor parameters, the image and data from the ultrasonic sensor. After localization, the robot attempts to grab it by moving its arm to the calculated object location in 3D space, and then reach for it accurately by error correction using the markers on its gripper. Object recognition can be further developed by using Haar Cascades, histogram of gradients (HOG), neural networks, etc., while retaining this simple technique of localizing an object in three-dimensional space. This algorithm can be used in miniature robotics where processing power is limited. Elements such as the shoulder joint can aid to improve design of prosthetics for greater dexterity. Miniature humanoid robots in hospitals can help engage children who have cognitive conditions. Achieve cost effective production of humanoids by open-sourcing hardware and software and 3D printing mechanical elements.

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