International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 07 | July 2020 www.irjet.net p-ISSN: 2395-0072

Design of a Shoulder Mounted Collaborative Robot for Household Tasks

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Abstract - *Collaborative Robots have been employed in the industrial environment for the past decade such as factories, workshops, warehouses, etc. There are various unexplored environments for a collaborative robot. A common household environment being the least explored with the most potential. A number of tasks are to be performed in a household, for example cleaning the kitchen table, handling a common tool, cooking, etc. These tasks appear to be linear and simple but some of them often require a third hand or some homely knowledge. The demographic of humans between the age of 20-30 often refrain from doing these tasks, reason being the physical and mental stress one incurs from them. The Collaborative Robot acts as a companion by employing the chat function, allowing users to interact in multiple ways, designed as a cobot in such a way that it helps improve the overall performance measures of the tasks and assists the user to perform the task. The system uses a Raspberry Pi as the main control unit and is coded in python, it uses TensorFlow and Machine Learning Concepts which forms the companion aspect.*

Key Words: Collaborative Robots, Python, Deep Learning, Deep Neural Network, Chatbot.

1. INTRODUCTION

The various tasks performed in a household appear to be miniscule and linear but are often complex and almost always require a helping hand. The demographic of humans of age between 20-30 have often developed signs of mental stress and physical pain due to these tasks. Collaborative robots are yet to be explored in a compact environment similar to a household. The ability to use collaborative robots has been explored in industrial environments such as warehouses, factories, packaging industries, etc. These robots have become undeniably popular in the last two decades because of their innate ability to improve the performance of any worker the robot is used with. Collaborative robots are easier to install, use and accommodate than industrial robots, they do not require highly skilled labour, a large workspace and are safe to work in close proximity to a human. Potentially collaborative robots are expected to work well in environments with close human contact and compact workspace. The ability of these robots to adapt to various environments according to the situation makes them very useful in a close quarter environment like a household. The household environment presents a variety of opportunities for the use of a collaborative robot. The person handling a household goes through various tasks in a day. These tasks often appear to be miniscule and linear but they are more complex and almost always require something more. The potential of collaborative robots in the household environment is thoroughly explored by this design. The robot is a shoulder mounted collaborative robot with a specialised chatbot for household environment. The chatbot was developed in Python which was further implemented on a Raspberry Pi. The interactive aspect of the collaborative robot is specialised such that it has a dataset of various tips and tricks, homely remedies along with a vast database of over 100 recipes of different cuisines spread over all the meals of the day. The product has a flexible grasper arm which has a lifting capacity of one and a half kilograms. The flexible arm has a gripping hand which uses two robotic fingertips to hold the given object. The robot has a mountable holder designed specifically for a shoulder of an average human. The extent of this robot design in the aforementioned environment is abundant.

1.1 Related Work

There have been several robots in the past decade being implemented to carry out services in the household environment and there are several methodologies to do these tasks.

The robot designed by Zhang Fuyan et al[1] is a mobile robot which is controlled by core controller STM32. The robot has a WIFI Camera and is able to traverse NAT to check the video data for each position. Furthermore it employs a server to establish communication between mobile and the robot.

Another type of service robot based on Android Platform was developed by Deng Zhi-Hui et al[2]. This robot has various sensors like temperature, humidity, smoke sensors with which it can sense the environment around it. The robot also has a camera through which it can navigate. The control unit is an Android based embedded system which further controls motion drivers, alarms and other actuators.

The developed Control System proposed in Xinhua Lin et al[3] uses advanced speech recognition techniques to control a domestic robot for performing day-to-day household work. The robot also has the ability to perform video surveillance and environmental monitoring.

In a survey publication by Sameera A. Abdul Kader et al[7] various techniques of developing a chatbot for specific conversational prowess are discussed and evaluated. The publication inspired us to use one of the best techniques to develop the chatbot used in this paper.

The robot proposed by us is different in many aspects than the existing models of service robots employed in the household environment. The major difference being mobility of the robot. The robot proposed in our designs is a non-mobile, shoulder mountable robot. Another key aspect which makes our robot distinct is the type of control used, the design mainly uses voice control through the Raspberry Pi without any different type of device to issue control orders.

2. CONCEPTUAL DESIGN

The collaborative household robot is provided with a microphone, speaker and a camera to ensure efficient interaction with the environment of the robot and the user which are controlled by the core controlling unit, Raspberry Pi 3. The robot has a flexible arm made out of ABS plastic, at the end of this arm is a robotic hand with two fingertips designed to hold objects with a weight of 1.5 kilograms by using an electric drive for actuating the gripping action. The gripping action of the robotic arm is controlled by using the voice of the user, picked up by the microphone. The user can guide the flexible arm to any desired position. The robot is interactive by the virtue of the trained machine learning model used to devise a chatbot. This interactivity also allows the robot to be controlled over voice by the user.

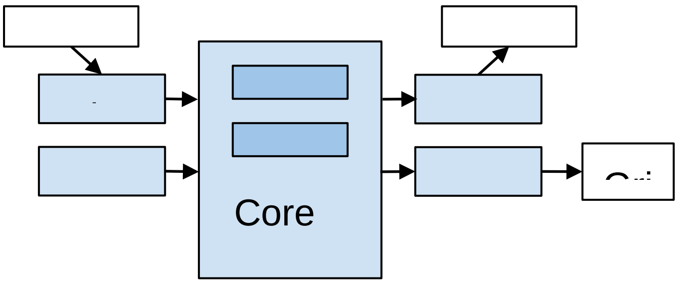

Fig -1: Concept Diagram of the System

Furthermore the designed robot also has the ability to provide the user with a number of recipes and homely remedies. This functionality is designed to be used through the chatbot using voice control functions. The conceptual design of the collaborative household robot is illustrated in Fig -1 by a line diagram of the designed system. Power unit used is essentially a rechargeable battery pack of Lithium-Ion batteries.

3. DESIGN OF COLLABORATIVE ROBOT

This section explores all the design aspects of the robot and the underlying processes and methodologies used to achieve the functions desired through these designs.

3.1 Conversational Chatbot

The conversational function of the robot is developed by using Machine Learning in Python. The dataset used for the machine learning model to train on was an intents type dataset. The conversations in the dataset are classified by tags which convey the intention of all conversations in that particular element. Along with the tags every element has two lists of possible conversational sentences classified as Patterns and Responses. Patterns are the part of the conversation spoken by the user and response is the part of the conversation spoken by the robot to those particular patterns. The dataset used has a set of over twenty thousand conversational possibilities. The example of the aforementioned dataset is shown below in Fig -2.

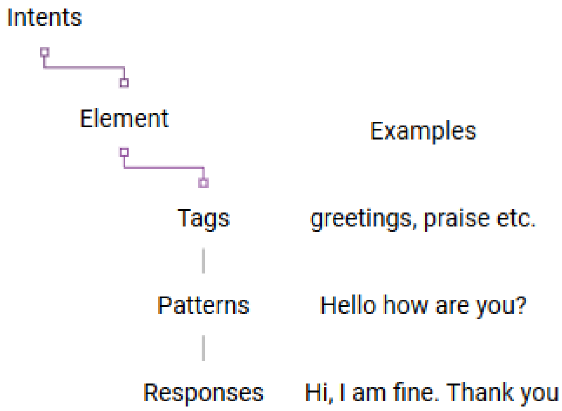

Fig -2: Structure of Dataset

The dataset is refined to obtain two arrays for the purpose of training the model, pattern and tag. The model is created using the tflearn library in Python. The Deep Neural Network model implements Linear Regression on the input with two hidden layers of eight nodes. Since the output is a probabilistic array, the tag with the maximum probability is chosen and a random response from the element with this tag is chosen as the response to the conversation.

3.2 Object Gripping Mechanism

The material chosen for the flexible arm of the robot is ABS Plastic. This material is flexible yet sturdy and can easily withstand loads upto 3 kilograms. The robotic hand with two fingertips is attached at the end of the flexible arm. The gripping hand is actuated by an electrically driven servo motor which is controlled by the voice of the user. The gripping mechanism used is a rack and pinion mechanism which is illustrated in the image given below, Fig -3. One of the two fingertips is non-mobile, attached to the housing of the hand whereas the other is a mobile fingertip connected to the rack. The pinion is coupled with the shaft of the servo motor which lays inside the housing. The rotation of the pinion is converted to the translational motion of the rack thus making the movable fingertip clench against the stationary fingertip. The module of the gear pair was calculated by considering a servo motor with the following specifications, as shown in the table below.

Table -1: Specifications of the Servo motor

Serial No.	Particulars	Details
1	Operating Voltage	4.8 V
2	Operating Current	2 Amperes
3	Torque Rating	0.0166 kW
4	Speed	0.1 second per 60 degrees of rotation

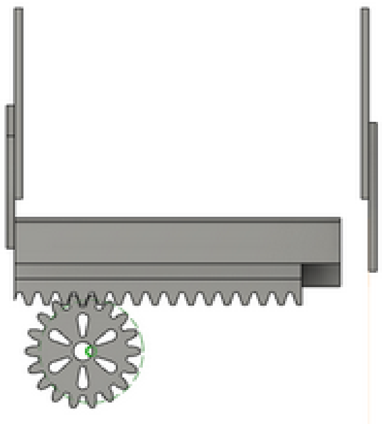

Fig -3: Gripping Mechanism of the Robot

The material chosen for the gear pair is Acrylic Plastic with a tensile strength of 69 MPa. This material was chosen due to the ease of manufacturing aspect along with the weight to strength ratio of the material. The module of the gears as determined was 1.43, approximated to 1.5. The dimensions of the hand and the geometric positioning of the fingertips puts a dimensional constraint on the object that can be placed and held in the gripper. The dimensions were considered such that it can cover most of the object which can be seen in the household environment. The dimensional constraints are explained in the following table.

Table -2: Dimensional Constraints of Objects to be held

	Length	Breadth	Height
Minimum	20 mm	NA	2.5 mm
Maximum	140 mm	140 mm	75 mm

The mechanism of rack and pinion, servo motor, wiring all reside inside the housing of the robotic hand which is designed to be manufactured from sheet metal aluminium of thickness 2 millimeters. The finger tips are provided with a rubber pad to achieve higher coefficient of friction between the object and the fingertips. The complete design of the robotic hand is illustrated below in Fig -4.

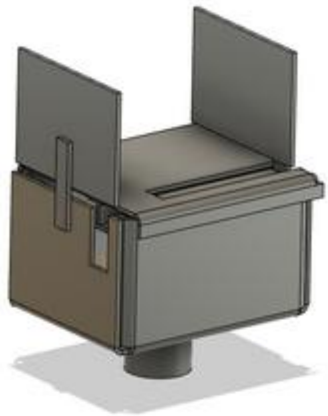

Fig -4: Robotic Hand with two Fingertips

The gripper is attached to the flexible arm by a small holder part and four nut bolt pairs.

3.3 Software Design

The code loaded into the system of the robot has a main python function which uses the trained Deep Neural Network model to predict the intention of the input voice command given by the user. The main function is enabled with an algorithm which calls specific functions if the intent of the user is to take benefit of functionalities. The various functionalities are realized through other sub-functions which can be called through the main function.

The functionality of running the recipe step by step is one such sub-function which is called in the main Conversational Chatbot function when the user has the intent of using the function. The function is activated when the user gives the voice command, “recipes”. The algorithm used to run the recipes by the user step by step is a simple loop which outputs all the information in a step-by-step manner. Firstly, the cuisine and the dish is chosen by the user by a voice search in the ‘dish_name’ element of the recipe dataset. After choosing a particular dish and the serving size the robot runs a simple loop which reads through the list of all steps involved in the recipe over the speaker.

The actuation of the gripper is also controlled through a sub-function which can be called by interacting with the Conversational Chatbot and showing the intent of controlling the gripper. The function for controlling the gripper is called when the system receives the voice command, "gripper control". The function then declares that the gripper control is activated and is ready for receiving further instructions from the user. The function has further commands like hold, leave, tighten, etc. Upon receiving the instructions by the user the system controls the fingertips of the robotic hand by controlling the servo motor through the driver. The rotation of the servo then causes the rack to slide in the direction issued by the voice command given by the user.

3.4 Hardware Design

The physical body of the robot was designed with the following considerations:

1. The overall dimensions of the robot has to be suitable for the shoulders of an average human.
2. The robot has to house a raspberry pi, a speaker, a microphone, a motor driver and necessary wiring.
3. The robot is supported by the shoulder and the upper body strength of an average human, thus the weight of the robot should be minimum.
4. The robot when mounted on the shoulder should not restrain any movement of the shoulder joint to provide maximum freedom of movement.
5. The flexible arm provided in the robot system should not interfere with the natural movements of the hands.
6. The mechanism used in mounting the robot should be strong enough to keep the robot in one place throughout rigorous tasks.
7. The speaker should be configured and placed in such a way that it does not hurt the auditory senses of the human.

The outer body of the robot is designed out of sheet metal aluminium. The Raspberry Pi is slotted inside a housing designed according to the dimensions of the chip. The inner body has specific housings for the parts to be fit. The speaker is housed on the top right corner, away from the head and the microphone is placed as close to the face as possible.

The robot is mounted on the shoulder of the user using a strap which is designed to wrap around the waist of the user to give a comfortable and sturdy mount.

The design of the entire robot is illustrated in the rendered image given below. The gripper is not shown below. It is designed to be attached at the end of the flexible arm.

Fig -5: Rendered Image of the Cobot

4. CONCLUSIONS

The potential of household robots is vast and is majorly unexplored. Our design of household robots explores the non-mobile and collaborative approach of robots to increase the comfort and standard of living. The collaborative household robot explores the benefits of artificial intelligence combined with robotics in a household environment. Household robots have a large market for the various functionalities they bring to the household like, servicing the household, navigating, performing tasks independently as well as collaboratively. The improvement in the standard of living by employing a household robot and the amount of comfort it can provide is a lot.

The household robot will improve the standard of living and the comfort level of the user. It will ease various household tasks by collaboratively making an efficient way to complete tasks. The physical and mental stress experienced by the user in performing tasks will be reduced by a significant amount. The simplistic design makes it affordable. The tasks performed using the robot will be superiorly efficient than normally performed jobs. The time and stress reduced from this can be used in creative tasks, working hours and many more worthwhile things.

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