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Voice-Controlled Assistive Robotic Arm – A Survey

Dr. Sandeep Awachar[1], Rushikesh Devikar[2], Snehal Deshmukh[3], Shrutika Kale[4], Shamal Wakode[5]

[1,2,3,4,5] Computer Science & Engineering Department, College of Engineering & Technology, Akola, Maharashtra, India

Abstract
Assistive technologies play a vital role in improving the quality of life for physically disabled individuals. Among various assistive devices, robotic arms have gained significant attention for helping people with upper limb disabilities perform daily tasks independently. This survey report presents a comprehensive review of existing research and technologies related to voice-controlled systems, assistive robotic arms, human–robot interaction, and intelligent automation. The objective of this survey is to understand current advancements, identify research gaps, and provide direction for the development of a Voice-Controlled Assistive Robotic Arm.

Keywords: Assistive Technology, Voice Recognition, Automation, Disabled, Rehabilitation Robotics, Robotic Arm.

1. Introduction

Physical disabilities affecting the upper limbs can significantly reduce a person's ability to perform everyday activities independently. According to global health studies, millions of individuals suffer from partial or complete loss of arm mobility due to injuries, neurological disorders, muscular dystrophy, stroke, or congenital disabilities. These individuals often rely heavily on caregivers for performing even basic tasks such as drinking water, picking up objects, or using electronic devices.

Assistive robotics has emerged as a rapidly growing research field aimed at addressing these challenges. Assistive robotic systems are designed to help individuals with disabilities perform tasks that would otherwise require human assistance. In particular, robotic arms have shown great potential in helping users manipulate objects, interact with their environment, and regain some level of independence.

Recently the new technological advancements in artificial intelligence, embedded systems, speech processing, and the Internet of Things (IoT) have made it possible to design intelligent robotic systems that can respond to user commands in real time. Among the different control interfaces available, voice control has proven to be one of the most convenient and natural methods for human-machine interaction.

Voice-controlled systems allow users to operate devices simply by speaking commands. This approach is particularly beneficial for individuals who cannot use traditional control methods such as keyboards, joysticks, or switches. Voice interfaces reduce physical effort and provide a more intuitive way of interacting with assistive devices.

The development of a Voice- Controlled Assistive Robotic Arm aims to combine robotics, speech recognition, and intelligent automation to create a system that can assist individuals with upper limb disabilities in performing everyday tasks. Such a system can respond to commands like “move left,” “pick object,” or “open gripper,” enabling users to control the robotic arm without physical interaction.

This survey report reviews existing research in assistive robotic technologies, speech recognition systems, and human- robot collaboration. It also examines different assistive solutions such as intelligent wheelchairs, voice-controlled home automation systems, and navigation robots for visually impaired individuals. By analyzing these technologies, the report aims to identify design approaches and research opportunities for developing an efficient and affordable voice-controlled robotic arm.

2. OVERVIEW OF ASSISTIVE ROBOTIC SYSTEMS

Intelligent Wheelchair Systems One notable development is IntellWheels, an intelligent wheelchair platform designed to assist severely disabled individuals who cannot operate traditional electric wheelchairs. The system integrates sensors and intelligent navigation modules to improve safety and autonomy. Although focused on mobility, the concept of intelligent assistance and sensor integration is directly applicable to robotic arm systems [1].

Mukesh Kumar and Shimi S. L. proposed a voice recognition based home automation system designed for paralyzed individuals. The main objective of their research was to enable physically disabled users to control household appliances through simple voice commands. The system uses a microcontroller along with a speech recognition module to interpret spoken instructions and convert them into electrical signals that operate devices such as lights, fans, and other home appliances through relay circuits. This approach reduces the dependence of paralyzed patients on caregivers and provides them with greater independence in managing their daily activities. The study demonstrates that voice-based interfaces can be an effective and user-friendly solution for assistive technologies, and similar concepts can be extended to control robotic systems such as assistive robotic arms [2].

Halawani, S. M. developed an Avatar-Based Translation System using the Sphinx-4 speech recognition engine to improve communication between humans and computer systems. The proposed system converts spoken language into text using the Sphinx-4 speech recognition framework and then translates the recognized speech into visual or animated outputs through an avatar interface. The research demonstrates the effectiveness of speech recognition technology in interpreting human voice commands and converting them into machine- understandable instructions. This study highlights the potential of speech processing systems for real-time human–computer interaction, which can also be applied in assistive technologies such as voice- controlled robotic arms where spoken commands are translated into robotic movements [3].

Yong, F., et al. proposed a deep learning based wearable healthcare IoT device designed to monitor and analyze human health conditions in real time. The system integrates wearable sensors, IoT communication modules, and deep learning algorithms to collect physiological data and detect health-related patterns. By processing sensor data through intelligent algorithms, the device can identify abnormal conditions and provide timely feedback to users or healthcare providers. The study demonstrates how artificial intelligence and IoT technologies can enhance the effectiveness of assistive healthcare systems. The concepts presented in this research can also support the development of intelligent assistive robotic devices, where sensor data and AI algorithms can improve system responsiveness, safety, and user interaction [4].

A. Tiwari proposed a gesture-based communication system designed for deaf and mute individuals to improve their ability to interact with others. The system uses sensors and pattern recognition techniques to detect hand gestures and convert them into readable text or audible speech signals. By interpreting human gestures through electronic devices, the system enables effective communication between differently abled individuals and the surrounding environment. This research highlights the importance of alternative human–machine interaction methods in assistive technologies. The concepts of gesture recognition and signal processing presented in this work can also contribute to the development of intelligent assistive robotic systems that respond to user commands through different input methods such as voice or gestures [5].

Mekhalfi, M. L. discussed the development of assistive smart technologies designed to support visually impaired individuals in their daily activities. The research focuses on intelligent systems that use sensors, embedded devices, and communication technologies to help blind users navigate environments, detect obstacles, and access information more easily. These assistive technologies aim to increase safety, independence, and mobility for visually impaired people by providing real-time feedback and guidance. The study highlights the importance of integrating smart sensors and intelligent algorithms in assistive systems. Such concepts can also be applied in robotic assistive devices, where sensor-based technologies can help robotic arms detect objects and perform tasks more safely and accurately [6].

J. Guerreiro et al. introduced CaBot, an autonomous navigation robot designed to assist visually impaired individuals in navigating complex environments. The system uses multiple sensors such as cameras, LiDAR, and obstacle detection modules to identify surrounding objects and determine safe navigation paths. CaBot provides guidance to users through haptic and audio feedback, allowing them to move safely and independently in indoor environments. The research demonstrates how robotics, sensor integration, and intelligent navigation algorithms can improve mobility for visually impaired individuals. The technologies used in CaBot, particularly obstacle detection and environmental sensing, can also be applied to assistive robotic arms to improve object detection, safe movement, and interaction with the surrounding environment [7].

Robert Bosch GmbH introduced the APAS (Automatic Production Assistant System) for human–robot collaboration in industrial environments. The APAS system is designed to work safely alongside human workers by assisting in repetitive or physically demanding tasks such as assembly, material handling, and precision operations. It uses advanced sensors and safety mechanisms that allow the robot to detect human presence and adjust its movements accordingly to prevent accidents. This collaborative approach improves productivity while reducing physical strain on workers. The concept of safe human–robot interaction presented in this research is highly relevant to assistive robotic systems, where robotic devices must operate safely and efficiently while interacting closely with users, especially individuals with physical disabilities [8].

S. Awachar proposed a leg- controlled artificial arm designed to assist individuals who have lost the ability to use their upper limbs. In this system, the movement of the robotic arm is controlled through foot-operated switches that send electrical signals to a microcontroller. The microcontroller processes these signals and activates DC motors that control the movement of different joints of the robotic arm. This approach provides an alternative method for controlling assistive robotic devices without using hand movements. The study demonstrates how simple control mechanisms and embedded systems can be used to develop low-cost assistive solutions. However, the system may not be suitable for individuals with disabilities affecting both upper and lower limbs, highlighting the need for more flexible control methods such as voice-based interfaces [9].

A. Rehman proposed a voice- controlled home automation system aimed at assisting elderly and physically disabled individuals in managing household appliances independently. The system utilizes speech recognition technology to interpret voice commands and control various electrical devices such as lights, fans, and other home appliances through a microcontroller-based control unit. By enabling users to operate devices using simple spoken instructions, the system reduces the need for physical effort and external assistance. This research highlights the effectiveness of voice-based interfaces in assistive technologies and demonstrates how speech recognition can improve accessibility and convenience for users. The concept can also be extended to robotic systems, where voice commands can be used to control the movements and functions of assistive robotic arms [10].

3. COMPONENTS REQUIRED FOR VOICE-CONTROLLED ASSISTIVE ROBOTIC ARM

The design of a voice-controlled assistive robotic arm involves the integration of several hardware and software elements that work together to interpret user commands and execute mechanical movements. These components form the basic architecture of the system and ensure smooth communication between the user and the robotic device. The hardware part is responsible for capturing voice input and performing physical actions, while the software part processes commands and controls the operation of the robotic arm. Proper coordination between these components is essential for the reliable functioning of the assistive system.

3.1 HARDWARE COMPONENTS

The hardware section of the system includes electronic and mechanical parts that physically perform the tasks. A microcontroller such as Arduino or ESP32 serves as the main control unit that processes the commands received from the speech recognition module and sends instructions to other components. Servo motors or DC motors are used to create movement in different joints of the robotic arm, allowing it to rotate, lift, and grip objects. To control these motors effectively, a motor driver circuit is required, which regulates the direction and speed of the motors based on signals received from the microcontroller.

The mechanical structure of the robotic arm consists of multiple joints and links designed to replicate the movement of a human arm. A power supply unit provides the necessary electrical energy to operate the microcontroller, motors, and other electronic modules. A microphone module is included to capture the user's voice commands and convert them into electrical signals for further processing. In addition, optional sensors such as ultrasonic sensors, infrared sensors, or cameras may be incorporated to detect obstacles, identify objects, or enhance the overall safety and efficiency of the robotic arm.

3.2 SOFTWARE COMPONENTS

The software part of the system is responsible for interpreting voice input and controlling the movement of the robotic arm. A speech recognition engine is used to analyze the captured voice signals and convert spoken words into digital commands. Once the voice command is recognized, a command processing algorithm interprets the instruction and determines the specific action that the robotic arm should perform.

After processing the command, the motor control logic generates the appropriate control signals that operate the motors and produce the desired movements of the robotic arm. To ensure reliable and safe operation, safety algorithms may also be implemented within the system. These algorithms help prevent unexpected movements, detect operational errors, and protect both the user and the robotic device during interaction. Together, these software components allow the robotic arm to respond accurately and efficiently to user voice commands.

4. WORKING PRINCIPLE

The proposed voice-controlled assistive robotic arm operates by converting spoken commands from the user into physical movements of the robotic arm. The process begins when the user gives a voice command such as “move up,” “move down,” “open,” or “close.” A microphone module connected to the system captures the user’s speech signal and converts it into an electrical audio signal. This signal is then sent to the speech recognition module, which analyzes the audio input and converts the spoken words into digital text or predefined command signals.

Once the command is recognized, it is transmitted to the microcontroller, which acts as the central control unit of the system. The microcontroller processes the received command and determines the required action to be performed by the robotic arm. Based on the command, the microcontroller sends control signals to the motor driver circuits that are connected to the servo motors or DC motors of the robotic arm. These motor drivers provide the necessary power and direction control required for the movement of the motors.

After receiving the control signals, the motors rotate accordingly, causing the joints of the robotic arm to move in the desired direction. For example, when the user gives the command “Move up,” the motor responsible for vertical movement rotates the arm upward. Similarly, when the command “Move down” is given, the arm moves downward. Commands such as “Open” and “Close” control the gripper mechanism of the robotic arm, allowing it to grasp or release objects. Through this sequence of operations, the robotic arm is able to perform various assistive tasks based on simple voice commands given by the user.

5. CONCLUSION

Assistive robotics is an emerging field that aims to improve the quality of life for individuals with physical disabilities. With the rapid advancements in Artificial Intelligence (AI), the Internet of Things (IoT), and embedded systems, assistive devices are becoming more efficient, intelligent, and user-friendly. Voice- controlled systems provide a natural and accessible way for users to interact with machines through simple spoken commands. This approach is particularly beneficial for individuals with limited mobility, as it eliminates the need for physical effort and complex control mechanisms. As a result, voice-based assistive technologies are gaining significant importance in rehabilitation robotics and human–computer interaction.

The development of a Voice- Controlled Assistive Robotic Arm can significantly enhance the independence of individuals with upper limb disabilities by helping them perform daily activities such as picking objects, moving items, or operating small devices. By integrating speech recognition technology with robotic mechanisms and intelligent control systems, such devices can provide an effective and affordable assistive solution. Future improvements may include the integration of AI-based object recognition, IoT connectivity for remote monitoring, mobile application interfaces, and machine learning-based voice training to improve speech recognition accuracy. These advancements can make assistive robotic systems more reliable, adaptable, and accessible for people who require support in their everyday lives.

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