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EC601

Robotic Arm for people using wheelchairs

Robotic arms are groundbreaking assistive tools designed to enhance the mobility and independence of individuals who face physical challenges. For people using wheelchairs, tasks as simple as picking up objects from the ground can be difficult. Robotic arms serve as extensions of their limbs, offering a solution to this problem.

1. Problem Statement:

The problem of robotic arms for people using wheelchairs is the limited range of motion and physical abilities of individuals with mobility impairments. To replicate the precision of human limbs, these robotic arms must be exceptionally flexible. However, this flexibility often comes at the cost of reduced lifting capacity. Striking the right balance between agility and strength is paramount.

2. Application:

Over the years, robotic arms have found various applications in assisting individuals with disabilities. But it can still be applied into many aspects:

(1) Instrument Playing: Robotic arms can assist wheelchair users in playing musical instruments, such as the piano, by rapidly adjusting their robotic fingers to create intricate melodies.

(2) Brainwave Control: For those who are paralyzed or unable to use their limbs to control the robotic arm, brainwave control offers an innovative solution. This technology allows individuals to achieve tasks they might have never imagined possible, purely through the power of their thoughts.

(3) Medical Procedures: In medical settings, these arms can be used to aid in precise surgical procedures, reducing the physical strain on healthcare professionals.

3. Model of Robotic Arm:

The robotic arm's coordinated movement is driven by the interaction of the joints. Hence, in order to completely understand and analyze the interaction, we can investigate and analyze the kinematic model of the joints – Denavit–Hartenberg(DH) parameters :

DH parameters are consist of four parameters : "r, α, d, θ". These four parameters can express how two joints work. Each jointis dined in its own coordinae system, which is x,y, and z .,axes, and the parameters are describing how much distant or angle it moves from one axis to another.

"r" stands for the distant from the z-axis to the next z-axis along the x-axis.

"α" represents the angle between the z-axis to the next z-axis along the x-axis.

"d" stands for the distant from the previous x-axis to the x-axis along the z-axis.

"θ" represents the angle between the previous x-axis to the x-axis along the z-axis.

In typical robotic arm configurations, joints are categorized into two fundamental types: prismatic and revolute joints, each with distinct modes of movement.

Prismatic joints facilitate linear motion, enabling an element of the robotic arm to move along a straight path. In this context, the DH parameter "d" is applicable, representing the linear displacement between consecutive joints along the arm's z-axis.

Conversely, revolute joints facilitate rotational motion, allowing a part of the robotic arm to rotate around a specific axis. For revolute joints, the DH parameter "θ" comes into play, characterizing the angular orientation between consecutive joints along the arm's z-axis.

With these four parameters, we can form a 4*4 DH matrix:

$$\begin{matrix} c\theta & -s\theta & 0 & \alpha \\ s\theta c\alpha & c\theta c\alpha & -s\alpha & -s\alpha d \\ s\theta s\alpha & c\theta s\alpha & c\alpha & c\alpha d \\ 0 & 0 & 0 & 1 \end{matrix}$$

, where c for cosine and s for sine.

These parameters are used to construct a 4x4 transformation matrix known as the Denavit-Hartenberg transformation matrix (DH matrix) for each joint. The DH matrix describes how to transform coordinates from one joint's reference frame to the next joint's reference frame. It combines translation along the z and x axes and rotation about the z and x axes.

Multiplying these DH matrices for each joint can compute the transformation from the base to the end-effector of the robotic arm, calculating the end-effector's position and orientation in the robot's base coordinate frame. These transformations are fundamental for solving kinematics problems and controlling the robot's movements accurately.

4. Simulation of a robotic arm :

A robotic arm is consist of complex system including sensors, controller, and actuators. Each part of the system collaborates with others to let the robotic arm conduct the demands and mission. In the meanwhile, each one of them effects others' decision. For example, a sensors can provide the controller the message of pictures and run the algorithm to give the actuators the commands to motors, and the motor can give the sensors position to process the next movement.

Therefore, we need a system to work as a bridge to connect them all. That's the ROS, robot operation system.

ROS can freely add new nodes and delete unnecessary nodes in the form of nodes to achieve modularization. It does not have high requirements for the processor, and can use open source code, eliminating the need to develop from scratch. ROS is now the main architecture for robot development.

(1) Structure of ROS:

The core components of the Robot Operating System (ROS) comprise Nodes, Messages, Topics, Publishers, and Subscribers, each playing a vital role in enabling efficient communication and coordination within a robotic system.

Nodes serve as computational entities that execute specific tasks or processes within the ROS ecosystem. These nodes can take various forms, such as sensors like cameras or infrared sensors capturing images, an image processing node implementing complex algorithms like

Convolutional Neural Networks (CNNs), or motor-controlling nodes transmitting signals to activate motors, thereby facilitating precise control over robotic movement.

Messages are essential data structures generated and exchanged by nodes. These messages are consist of information required for nodes to communicate effectively. Messages can contain diverse data types, including sensor data, control commands, or status updates, facilitating seamless information exchange.

Topics function as communication channels or buses through which nodes transmit and receive messages. Importantly, messages are not directly routed to their destination nodes. Instead, they are published onto specific topics, serving as a central point for data dissemination. Any node interested in a particular type of information can subscribe to the corresponding topic to access relevant data.

Publishers and Subscribers are the roles of nodes concerning message transmission and reception. A Publisher is responsible for transmitting messages onto a specific topic. This process is called "publishing" and ensures that information is transmitted to the appropriate audience within the ROS network. Conversely, a Subscriber is a node to receive and process messages from a particular topic, a process referred to as "subscribing." Subscribers enable nodes to access and utilize data relevant to their specific functionalities.

(2) OS for ROS:

ROS can be used on any operation system, like Mac OS, Windows 11, or Linux. However, it may be rigid to work on a Windows and Mac OS. Therefore, it's common to use ROS on the Linux system.

(3) Gazebo and ROS:

Gazebo is an open-source 3D robotics simulator. Gazebo simulated real-world physics in a high fidelity simulation. It helps developers rapidly test algorithms and design robots in digital environments. Gazebo helps developers integrate a multitude of sensors, and it gives the tools to test these sensors.

5. Future Prospect and Next Steps:

(1) Target Users:

The target users for a robotic arm are definitely people using wheelchairs. Furthermore, besides those who cannot move by their legs, we also want to apply this product to people who are paralyzed or cannot move their limbs. In that way, we can actually help more people who is physically challenged.

(2) Impact on the project:

Because we want to develop the robotic arm for all people with wheelchairs, our user interface must be diverse. Instead of just using screen to control the robotic arm, we can add gesture control, eye-movement control, facial-muscle control, or even brainwave control.

(3) Next Step:

Our immediate focus will be on working with ROS and Gazebo. We will analyze existing

Gazebo models of robotic arms and begin designing our own. Familiarity with ROS and Gazebo is essential as we move forward with the project.

6. ChatGPT results comparing:

(1) ChatGPT results:

Title: "Enhancing Mobility and Independence: The Role of Robotic Arms for Individuals Using Wheelchairs"

Robotic arms are innovative assistive tools designed to revolutionize the lives of individuals who rely on wheelchairs due to physical limitations. This comprehensive overview explores the potential of robotic arms to empower these users by addressing their unique challenges and offering newfound mobility and independence.

The challenges faced by wheelchair users, including limited range of motion and physical capabilities, are discussed. Robotic arms are presented as a transformative solution that replicates and enhances the precision of human limbs. Striking the right balance between agility and strength is paramount in their design.

Applications of robotic arms for wheelchair users are explored, including their use in instrument playing, brainwave control, and medical procedures. These applications illustrate the versatility and life-changing potential of these devices in various domains.

A fundamental understanding of robotic arm kinematics is provided through the Denavit-Hartenberg (DH) parameters, highlighting the importance of these parameters in controlling and modeling the arm's motion.

The significance of the Robot Operating System (ROS) in the functionality of robotic arms is emphasized. ROS serves as a crucial bridge that connects sensors, controllers, and actuators, allowing for modularization, flexibility, and ease of development. The ROS structure, encompassing nodes, messages, topics, publishers, and subscribers, is explained in detail.

Operating systems for ROS, such as Linux, are discussed in terms of their suitability and compatibility with open-source software, making them the preferred choice for deploying ROS.

The integration of Gazebo, an open-source 3D robotics simulator, is explored in the context of robotic arm development. Gazebo's high-fidelity simulation environment replicates real-world physics and facilitates the rapid testing of algorithms and design iterations.

Future prospects for robotic arms include expanding their user interfaces to accommodate diverse control methods, such as gesture control, eye-movement control, facial-muscle control, and brainwave control. These innovations aim to make robotic arms accessible to a broader range of users with varying physical abilities.

In conclusion, robotic arms represent a promising avenue for enhancing the lives of individuals using wheelchairs or facing mobility challenges. As technology continues to advance and the integration of ROS and Gazebo deepens, these devices hold the potential to provide greater freedom and independence to those who have long grappled with physical barriers.

(2) Analyzing:

The article is well-structured, with a clear introduction, problem statement, and well-defined sections that cover various aspects of the topic. It balances technical information with real-world applications, making it accessible to a general audience interested in the subject. The article provides a comprehensive overview of the topic while leaving room for further exploration and expansion on specific aspects to engage and inform the reader effectively.

Reference & Sources

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(7) Comparison between ROS and ROS2