Literature Survey

Head and Neck Gesture-Controlled Assistive Wheelchair

Assistive wheelchairs operated by head or neck gestures have gained significant attention in recent years to address the mobility challenges faced by individuals with quadriplegia. Conventional electric wheelchairs are generally designed for users with functioning upper limbs; however, for individuals who have lost control over their arms and legs due to spinal cord injuries, stroke, or muscular diseases, alternative control strategies become imperative. Research has shown that head motion remains one of the most reliable sources of voluntary movement for such users, leading to the exploration of head gesture-based wheelchair control systems.

Early works have demonstrated the potential of using inertial measurement units (IMUs) to detect head tilts and translate them into directional commands for wheelchair navigation. Pajkanović and Dokić introduced a system utilizing an accelerometer-based head motion recognition algorithm to control a wheelchair joystick via mechanical actuators. Their approach emphasized the use of simple threshold-based detection, allowing four basic movements: forward, backward, left, and right, by detecting leaning motions of the head in respective directions. The processing was performed using a microcontroller, enabling a cost-effective solution adaptable to various standard electric wheelchairs.

Subsequent developments incorporated improvements in sensor fusion and control logic. Systems based on MEMS accelerometers and gyroscopes, such as the MPU6050, have enhanced accuracy in detecting subtle head gestures. Researchers like Karthikeyan et al. proposed a neck movement-based wheelchair control where an accelerometer mounted on the user's neck captured tilt directions. In their design, the NodeMCU microcontroller processed accelerometer data and commanded the motors accordingly. Additionally, the system included auxiliary modules such as ultrasonic sensors for obstacle avoidance, temperature and heartbeat sensors for health monitoring, and Android app integration via Blynk to provide manual override control.

Another notable contribution was presented by Rekha and Sheetal, where a smart wheelchair controlled via head motion was integrated with Internet of Things (IoT) functionalities. They employed an MPU6050 sensor, connected via Bluetooth modules, and used Arduino-based processing to interpret head tilts. In addition to basic directional control, their system introduced real-time obstacle detection, patient pulse monitoring, and GSM-based emergency alert messaging when critical health parameters were detected.

Azraai et al. developed a head gesture-controlled wheelchair using a gyro-accelerometer system, focusing on lightweight and minimalistic design. Their system processed head pitch and roll movements, mapping specific angular thresholds to forward, backward, left, and right motions. An Arduino Nano-based processing unit combined with an nRF24L01+ wireless transceiver provided reliable data transmission to the wheelchair base unit. Their experiments showed a minimal average maneuvering error of 3–5 cm, highlighting the practical feasibility of this method even on rough surfaces.

Despite these advancements, several limitations persist across existing systems. First, the reliability of gesture detection highly depends on the correct placement and calibration of the sensors. Minor shifts in the wearable device can lead to misinterpretations of user intent. While simple threshold-based algorithms are efficient, they are susceptible to false positives due to involuntary head movements or environmental vibrations. Systems operating on predefined angles often lack adaptability across different users with varying levels of neck muscle control.

Wireless communication latency and energy consumption pose additional challenges. Bluetooth and Wi-Fi modules introduce transmission delays, particularly when integrated with cloud-based monitoring platforms. Real-time responsiveness is critical in navigation tasks, and latency can degrade the user experience or even result in accidents.

Moreover, the majority of prototypes have been validated in controlled environments with smooth terrains. Limited research has been conducted on system robustness over inclined, uneven, or outdoor surfaces where wheelchair control becomes more complex. Motor control schemes need to adapt to terrain variations, which current systems often overlook.

Affordability and accessibility also remain key concerns. Although researchers emphasize low-cost designs, adding multiple features such as obstacle detection, health monitoring, and wireless communication inevitably increases system complexity and cost. A balance between functional richness and cost-effectiveness is essential, particularly to serve economically disadvantaged users.

Another research gap lies in holistic integration. Most projects have treated gesture control, obstacle avoidance, and health monitoring as independent modules rather than deeply integrated subsystems. Seamless integration with minimal power and computational overhead would significantly enhance the system's reliability and usability. Additionally, user-centric aspects such as comfort of wearing the sensor module, ease of calibration, fatigue over long-term use, and adaptability to individual differences require further exploration.

In conclusion, existing head and neck gesture-controlled wheelchair systems demonstrate promising advancements in restoring partial mobility to individuals with severe physical disabilities. However, challenges related to sensor accuracy, environmental adaptability, latency, cost, and integrated design remain open for research. Future solutions must aim for highly robust, low-cost, and user-friendly systems that combine precise head gesture detection with smart navigation, obstacle avoidance, and vital health monitoring to truly empower users towards independent mobility.

Abstract

Head and Neck Gesture-Controlled Assistive Wheelchair: An Integrated Low-Cost System

Quadriplegic patients face significant mobility challenges due to the complete loss of voluntary control below the neck. In response to this need, a head and neck gesture-controlled wheelchair is proposed, offering intuitive and independent navigation based on minimal head movements. The proposed system integrates inertial sensing, wireless communication, obstacle detection, and health monitoring into a compact, cost-effective, and user-friendly architecture.

The system architecture consists of two major modules: a wearable head unit and a wheelchair base control unit. The wearable module includes a lightweight Inertial Measurement Unit (IMU), specifically an MPU6050 sensor combining a three-axis accelerometer and gyroscope. The sensor is mounted securely on a headband or neck collar to capture head pitch and roll motions. An Arduino Nano microcontroller processes the IMU data using a sensor fusion algorithm, filtering noise and deriving real-time tilt angles. A threshold-based gesture recognition logic interprets intentional movements into control commands—forward, backward, left, or right—while ignoring minor, unintentional head shifts.

Wireless communication between the wearable unit and the wheelchair control system is achieved through a Bluetooth Low Energy (BLE) module, ensuring low-latency transmission of motion

commands. On the receiving side, an Arduino Uno-based controller drives two DC motors via an H-bridge motor driver. Ultrasonic sensors mounted on the wheelchair detect nearby obstacles and override movement commands if a collision threat is identified. This real-time obstacle avoidance mechanism enhances operational safety.

In addition to navigation, the system incorporates patient health monitoring. A fingertip pulse sensor measures the heart rate, while a contactless infrared temperature sensor monitors body temperature. These sensors are interfaced with the wheelchair's microcontroller and connected via an ESP8266 Wi-Fi module to a cloud-based dashboard, enabling real-time health parameter monitoring and automatic alert generation if abnormal conditions are detected.

The proposed gesture recognition algorithm offers customizable calibration for each user, allowing threshold angles to be adjusted according to individual neck strength and range of motion. The system includes an intuitive calibration phase during startup, where a neutral head position is recorded. Intentional tilts beyond ±15 to ±20 degrees trigger respective movement commands, with added hysteresis and timeout features to prevent erratic behavior.

Emphasis has been placed on system affordability and modularity. All components, including sensors, controllers, and communication modules, are standard off-the-shelf parts, minimizing manufacturing costs. Moreover, the modular design enables easy maintenance and upgrading of individual subsystems without overhauling the entire setup.

The integration of gesture control, obstacle detection, and health monitoring into a single, coherent platform represents a significant step forward in assistive mobility technologies. Preliminary experimental validation on a prototype system shows high responsiveness, low command latency, and effective obstacle avoidance. Future work will focus on enhancing terrain adaptability, minimizing calibration complexity, and conducting extensive trials with actual quadriplegic users to refine the system for real-world deployment.