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Article · June 2024

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International Journal of Automation and Safety (IJAS)

Vol 02, N° 01, June, 2024, pp. 07-10

Journal homepage: https://www.asjp.cerist.dz/en/PresentationRevue/944

Enhancing Mobility for Individuals with Disabilities: A Computer Vision-Based Approach to Electric Wheelchair Control

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Received: March 26th 2024
Accepted: April 08th 2024
Published: June 30th 2024

Keywords:
Motorized electric wheelchair, artificial intelligence, computer vision, control, simulation.

ABSTRACT

In this work, we utilized a branch of artificial intelligence known as computer vision to provide easy and possible control of motorized wheelchairs in some special cases. We recognized that many disabled individuals who are unable to use their hands face challenges in operating traditional control sticks. Thus, we proposed a system that controls the wheelchair's movement by tracking the individual's head direction through a fixed camera placed in front of it. This means the wheelchair only moves based on the user's intended path as determined by their visual focus. This work has been successfully implemented in a simulated environment.

1. INTRODUCTION

The For individuals with disabilities affecting their hand mobility, controlling motorized wheelchairs using traditional control sticks can be challenging and limiting. In such cases, innovative solutions leveraging computer vision technologies can significantly enhance accessibility and ease of use. This paper presents a novel approach utilizing computer vision to enable seamless control of motorized wheelchairs based on the user's head direction, thereby offering a more intuitive and efficient control mechanism for individuals with limited hand mobility.

The inspiration for this work stems from the recognition of the challenges faced by disabled individuals who may struggle with conventional wheelchair control methods. By harnessing the power of computer vision, we aim to provide a practical solution that empowers users to navigate their surroundings with ease and independence. Our system tracks the user's head direction through a fixed camera positioned in front of the wheelchair, translating their visual focus into precise control commands for steering the wheelchair along their intended path.

Artificial intelligence (AI) has revolutionized the field of control systems by offering advanced algorithms and techniques that enhance efficiency, adaptability, and intelligence in various applications. For instance, AI-based control systems have been applied in autonomous vehicles, where deep learning algorithms help in real-time decision-making for navigation and obstacle avoidance [1].

Moreover, AI plays a crucial role in optimizing control parameters and enhancing performance in complex systems. Reinforcement learning techniques, such as deep Q-learning, have been utilized to optimize control policies in challenging environments, leading to improved control accuracy and robustness [2]. Additionally, AI-driven predictive control models have been developed for predictive maintenance in robotic systems, allowing for proactive system monitoring and fault detection [3].

As for the type of artificial intelligence that concerns us, which is Computer Vision, it has also been widely used in controlling various systems and robots. With regard to electric wheelchairs, many Computer Vision technologies have been used in order to provide easy and effective control for them, such as including head-controlled interfaces [4], eye-tracking systems [5], and gesture-based controls [6]. However, our approach stands out by focusing specifically on head direction tracking as a reliable and intuitive input method for wheelchair navigation.

This paper introduces an advanced control system for electric wheelchairs, utilizing state-of-the-art computer vision technology. It covers key areas such as wheelchair modeling, control design, and simulation results. The innovative approach allows wheelchair control through head movements, promising improved accessibility and independence for users with mobility challenges.

2. WHEELCHAIR MODELING

The kinematic model utilized for an electric wheelchair is grounded on a differential drive system, featuring two driving wheels capable of independent rotation [7].

This model encompasses three crucial variables: position, orientation, and velocity.

$$x(t) = \int V(t)\cos(\theta)dt \quad (1)$$
$$y(t) = \int V(t)\sin(\theta)\, dt \quad (2)$$
$$\theta(t) = \int \omega(t)dt \quad (3)$$

- Position, denoted as (x, y), and signifies the wheelchair's central location within the x-y plane.
- Orientation is characterized by the angle θ, which delineates the wheelchair's facing direction concerning the x-axis, measured in radians (see Figure 1).
- Velocity is articulated as (V, ω), where V symbolizes the wheelchair's linear velocity in meters per second (m/s), while ω signifies the angular velocity in radians per second (rad/s).

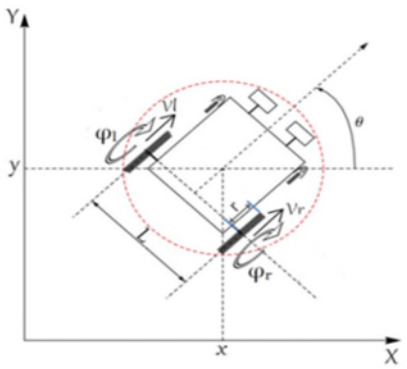

Figure. 1 Position of the Wheelchair in a 2D Coordinate System (adapted from [8]; revised for enhanced clarity).

The equations governing the relationship between velocity and orientation are crucial in characterizing the wheelchair's movement. Particularly, the correlation between the velocities of the right (Vr) and left (VL) wheels and the distance separating the two driving wheels (L) can be articulated as follows:

$$V = \frac{1}{2}(V_r + V_L) \quad (4)$$
$$\omega = \frac{1}{L}(V_r - V_L) \quad (5)$$

The Inverse Kinematic Model:

The inverse kinematic framework of an electric wheelchair delineates the velocities required for its left and right driving wheels to accomplish a specific motion pattern. These velocities are derived by solving the direct kinematic equations (4, 5) to obtain the wheel velocities concerning the wheelchair's linear and angular motions. This inverse model will be used in calculating the resulted right and left driving wheels velocities Compatible with steering the wheelchair by head movement, as we will explain later.

The resulting inverse kinematic equations can be formulated as follows:

$$V_r = V + \frac{L}{2}\omega \quad (6)$$
$$V_L = V - \frac{L}{2}\omega \quad (7)$$

3. CONTROL DESIGN

To realize and simulate our control approach we employed a computer camera to measure the rotational angle of the user's head, which dynamically adjusts based on the desired path traversal. The detected angle of head rotation correlates directly to the differential velocities of the wheelchair's right and left wheels, established through specific equations. Subsequently, the determined velocities dictate the directional movement of the wheelchair, enabling wheelchair aligned motion.

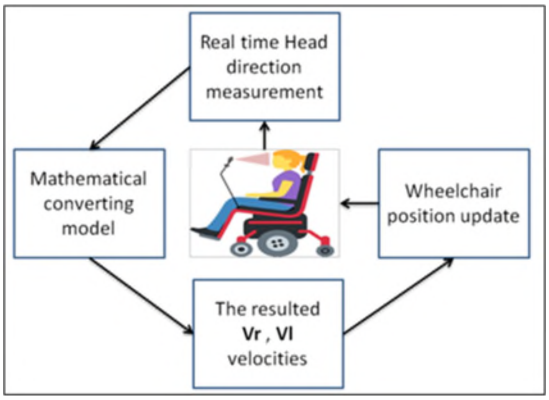

Figure. 2 Head direction Controlled Wheelchair mechanism

OpenCV library

OpenCV, an acronym for Open Source Computer Vision, is a freely available library with over 500 optimized algorithms for image and video analysis. It has become the primary development tool for researchers and developers in computer vision since its introduction in 1999 by Intel Corporation [9]. This tool is widely used for: Facial recognition, Object Detection, Motion tracking, Segmentation and recognition and many other applications [10].

In our work, we used one of the tools provided by the OpenCV library in order to measure the angle of head rotation, where we can obtain a numerical value ranging from -90 (if the head is turned to the extreme left) and +90 (if the head is turned to the extreme right), which represents In fact, the angle of view of a disabled person ϕ.

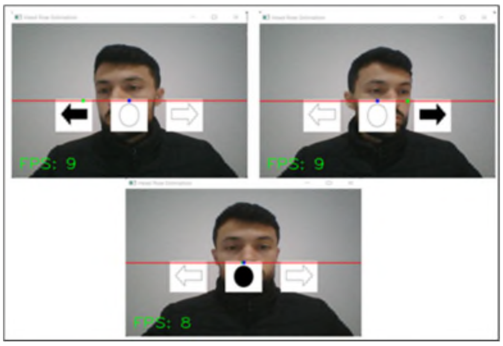

Figure. 3 Head angle rotation detection

After determining the angle ϕ, the next step is to determine how this angle affects the wheelchair's movement direction.

Initially, we assumed that the wheelchair has a constant initial linear speed of V0 = 0.25 m/s during straight movement. Furthermore, we established that each driving wheel can achieve a maximum linear speed of 0.6 m/s and a minimum speed of -0.1 m/s during rotational movement. This translates to the following constraints:

$$-0.1 \le V_r, V_L \le 0.6 \quad (8)$$

Which give :

$$-0.1 \le V_0 + k \le 0.6 \quad (9)$$

Where k represents: velocity adjustment factor

So:

$$|k| \le 0.35 \quad (10)$$

This means when we want to rotate the wheelchair, the value of the speed added to one of the rotating wheels will be subtracted at the same time from the other wheel to produce a rotational movement, and the value of this speed does not exceed the value of k_max=0.35.

Additionally, considering the angle ϕ lies within the range of [-09, 90] degrees, and according to k_max value, we can calculate the velocities of the right (V_r) and left (V_L) wheels as follows:

$$V_r = V_0 + \frac{k_{max}}{\phi_{max}} \phi \quad (11)$$

$$V_r = V_0 - \frac{k_{max}}{\phi_{max}} \phi \quad (12)$$

With:

$\phi_{max} = 90$

4. SIMULATION AND RESULT

In this section, the simulation was executed using the Python Integrated Development Environment (IDE) PyCharm. The camera utilized for the simulation was the built-in camera of an HP Envy laptop, equipped with an Intel(R) Core(TM) i7-7500U CPU running at 2.70GHz, with 2904 MHz, 2 cores, 4 logical processors, and 12 GB of Random Access Memory (RAM). The simulation involved following a predefined path that was drawn beforehand. The wheelchair's movement was controlled in real time through head movements, allowing for the assessment of trajectory tracking accuracy and system responsiveness under controlled and predetermined conditions. This setup facilitated a thorough evaluation of the proposed control methodology's performance and capabilities in navigating a predefined path using the described controlling approach.

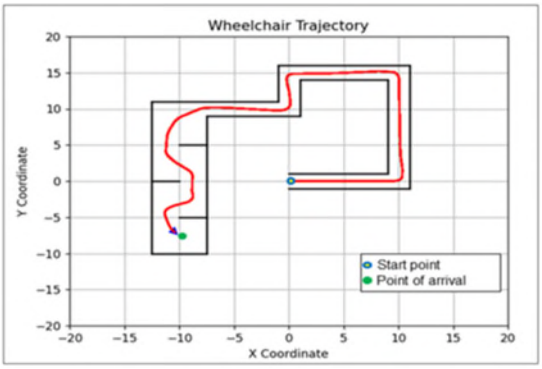

Figure. 4 The path and the trajectory of controlled wheelchair

Figure 4 illustrates the results of our real-time simulation. In the figure, the wheelchair is depicted in blue triangle, starting from the coordinates (0,0). We controlled its movement by tracking head movements along the path indicated by the black lines, successfully guiding it to the target point in green at coordinates (-10,-8).

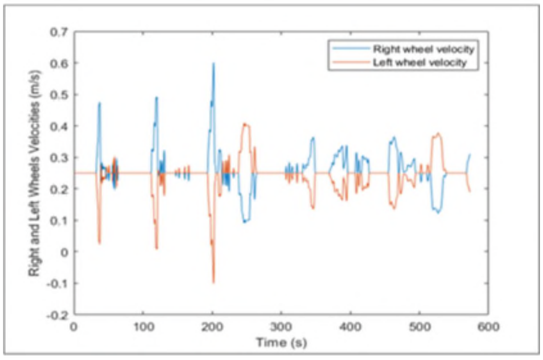

Figure. 5 The variation of right and left wheels velocities

5. CONCLUSION

Our proposed system, utilizing computer vision technology, offers a novel solution to the challenges encountered by individuals unable to operate conventional controls. Through precise head direction tracking via a fixed camera setup, the wheelchair seamlessly aligns its movements with the user's intended path, guided by their visual focus. This innovative approach not only demonstrates its feasibility and functionality within a simulated environment but also highlights its potential to revolutionize wheelchair control, providing a user-centric and intuitive interface.

The integration of computer vision technology in wheelchair control represents a significant advancement in accessibility solutions for individuals facing limitations with traditional control mechanisms. By accurately tracking head movements and translating them into precise wheelchair movements, our system shows promise in enhancing independence and mobility for users. This successful implementation within a simulated environment underscores the potential impact of this technology on improving the quality of life for individuals with mobility impairments.

REFERENCES

[1] P. Patthanajitsilp and P. Chongstitvatana**. "Obstacles Detection for Electric Wheelchair with Computer Vision," 2022 14th International Conference on Knowledge and Smart Technology, Thailand.

[2] Youcef, Z., & Pierre, C. (2004, May). Control of the trajectory of a hexapod robot based on distributed Q-learning. In 2004 IEEE International Symposium on Industrial Electronics (Vol. 1, pp. 277-282). IEEE.

[3] Chakroun, A., Hani, Y., Elmhamedi, A., & Masmoudi, F. (2024). A predictive maintenance model for health assessment of an assembly robot based on machine learning in the context of smart plant. Journal of Intelligent Manufacturing, 1-19.

[4] A. Jackowski, M. Gebhard and A. Gräser, "A novel head gesture based interface for hands-free control of a robot," 2016 IEEE International Symposium on Medical Measurements and Applications (MeMeA), Benevento, Italy, 2016, pp. 1-6.

[5] Wanluk, N., Visitsattapongse, S., Juhong, A., & Pintavirooj, C. (2016, December). Smart wheelchair based on eye tracking. In 2016 9th Biomedical Engineering International Conference (BMEiCON) (pp. 1-4). IEEE.

[6] Joseph, C., Aswin, S., & Prasad, J. S. (2019, March). Voice and gesture controlled wheelchair. In 2019 3rd International conference on computing methodologies and communication (ICCMC) (pp. 29-34). IEEE.

[7] Maatoug, K., Njah, M., & Jallouli, M. (2019, March). Electric wheelchair trajectory tracking control based on fuzzy logic controller. 2019 19th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering (STA). Presented at the 2019 19th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering (STA), Sousse, Tunisia.

[8] Kumar, S. A., Vanualailai, J., & Prasad, A. (2021). Assistive technology: autonomous wheelchair in obstacle-ridden environment. PeerJ, 7, e725.

[9] Laganiere, R. (2014). OpenCV computer vision application programming cookbook second edition. Packt Publishing Ltd.

[10] Adusumalli, H., Kalyani, D., Sri, R. K., Pratapteja, M., & Rao, P. P. (2021, February). Face mask detection using opencv. In 2021 Third International Conference on Intelligent Communication Technologies and Virtual Mobile Networks (ICICV) (pp. 1304-1309). IEEE.