18th International Conference on Innovative Computing, Information and Control (ICICIC2024)
Onsite (Qinhuangdao, China) and Online, September 10-13, 2024

PS-25: ICICIC2024-154

Obstacle Avoidance Control Method for Wheelchair Robots Considering Operating Habits and Fatigue State of User

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Introduction

Shared control methods for wheelchair robots aim to balance human intention and environment perception to accomplish robot motion planning and provide navigation assistance to humans. However, different users have different individual operating habits, which have an impact on the shared motion control of intelligent wheelchair robots. Furthermore, user's fatigue state also affects the safety of shared control. In this work, we propose a novel shared control system that takes into account both operating habits and physical states, which introduces a dynamic reinforcement learning strategy to adapt itself to the user's operating habits, and also establishes a mental fatigue detection model to monitor the user's fatigue state to further ensure the user's safety. Firstly, we utilize a reinforcement learning strategy to dynamically adjust the user control weights in the shared control to adapt to different individual habits. Then, to further improve the safety of shared control oriented to user's fatigue state, we introduce a pulse wave blood pressure sensor to detect the user's brain fatigue. Especially, we establish a mental fatigue detection model based on the variation of heart rate to measure the user's fatigue factor to realize the monitoring of the user's individual and fatigue state. Finally, in order to evaluate the performance of the proposed method, we conducted experiments to verify the effectiveness of the proposed algorithm.

Research Questions

How can a shared control system for intelligent wheelchair robots be designed to account for both the individual operating habits and physical states (specifically mental fatigue) of users, thereby enhancing the safety and effectiveness of robot-assisted navigation?

Mathematical Formulas

Reinforcement learning strategies are rewarded based on the following formulas

$$R_t = \begin{cases} R_0 & \text{if collision happens} \\ R_1 + R_2 + R_3 & \text{otherwise} \end{cases} \tag{1}$$

$$R_1 = K_1 \times tanh(d - d_s) \tag{2}$$

$$R_2 = K_2 \times e^{\frac{-|\beta_c|^2}{1458}} \tag{3}$$

$$R_3 = K_3 \times (\beta_{c_t} - \beta_{c_{t-1}}) \tag{4}$$

The formula for the control wheelchair is

$$\beta_s = \beta_a (w + a) + \beta_h (1 - (w + a)) \tag{5}$$

The optimal decision function for the fatigue detection model is

$$\begin{aligned} f(x) &= \operatorname{sgn}\left[w \cdot \phi(x) + b \right] \\ &= \operatorname{sgn}\left[\sum_{i=1}^{N} y_i a_i K(x_i \cdot x) + b \right] \end{aligned} \tag{6}$$

Methodologies

Dynamic Reinforcement Learning Strategy: To address the variability in individual operating habits, the researchers implemented a dynamic reinforcement learning (RL) strategy within the shared control system.

Mental Fatigue Detection Model: Recognizing that a user's mental fatigue can significantly impact the safety and efficacy of shared control, the researchers introduced a mental fatigue detection model.

Tables

Table 1. SVM classification results

Fatigue level	Number of test samples	Predicted accurate sample size	Accuracy
Normal state	200	180	90%
Fatigue state	200	168	84%

Figures

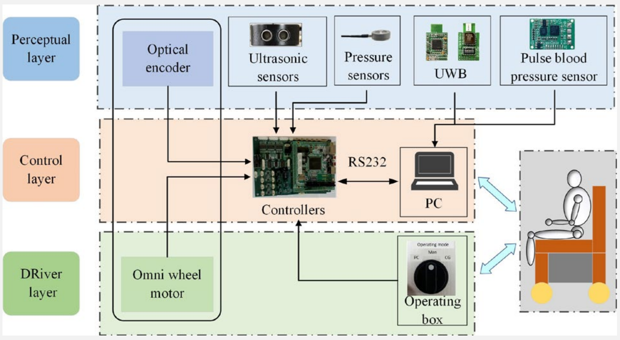

Figure 1. Data communication schematic

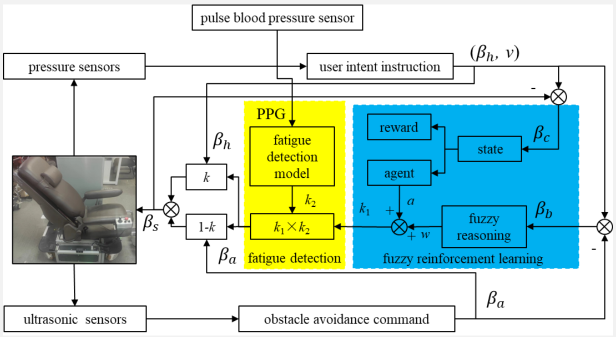

Figure 2. System block diagram

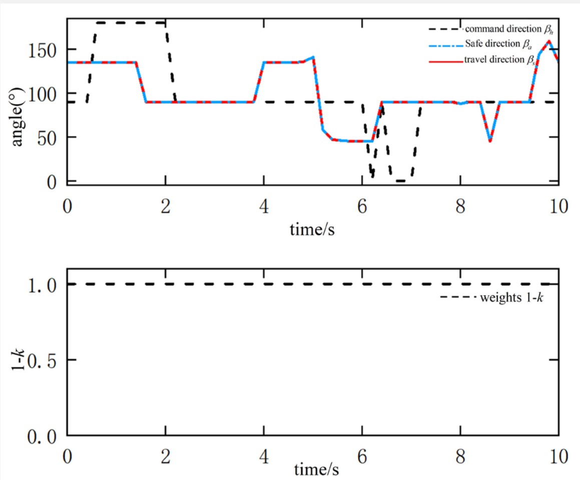

Figure 3. Correlated data changes in fatigue

Conclusion

This paper proposes a human-robot shared intelligent obstacle avoidance method for wheelchair robots considering operating habits and body states. The shared control scheme based on reinforcement learning is sufficient to acquire the characteristics of the user's operating habits and automatically adapt to the user's behavior to improve the user's comfort. Then, the detected user fatigue is applied to the designed state fusion shared controller, which enables the controller to take into account both operating habits and individual states, thus further improving the comfort and safety of user operation. The fatigue detection model designed in this paper has a recognition success rate of 87% and can better recognize the fatigue state of the user. In the future, for better monitoring, we will introduce other sensors to improve the recognition rate.