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An Approach for Fuzzy Control of Elderly-assistant & Walking-assistant Robot

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Abstract - With the rapid development of elderly-assistant & walking-assistant robot. How to improve the intelligent level of elderly-assistant & walking-assistant robot has become a research focus in recent years. In order to improve the control accuracy of movement-mode of elderly-assistant & walking-assistant robot and meet the user's requirements for robot control. In this paper, a fuzzy control method of robot movement is proposed, which is base on tactile-slip sensor detection system of elderly-assistant & walking-assistant robot. Firstly, the tactile-slip sensor detection system collect the tactile-slip signal and process the signals. Then, the walking-mode of elderly-assistant & walking-assistant robot is controlled by using the fuzzy algorithm method. The fuzzy control method was simulated through MATLAB to verify its feasibility, and the result shows it can effectively control the movement-mode of elderly-assistant & walking-assistant robot.

Keywords -Walking-mode; Fuzzy control algorithm; Elderly-assistant; Walking-assistant.

1. Introduction

Elderly-assistant & walking-assistant robot is a kind of intelligent service robot, the user use man-machine interface to participate in robot control. How to effectively control the movement-mode of elderly-assistant & walking-assistant robot is an important aspect of robot intelligence level. The correct control of the robot's movement-mode can ensure the robot moves according to people's intentions and reduce the wrong action of the robot. So, we need to find a better method to dealing with the problem.

In recent years, many domestic and foreign scholars have spent a lot of time in the field of service robot, but only a small number of the robot are able to accurately to control the robot according to the intention of human. There are the following studies: (1) University College Dublin developed a PAM-AID walker, the main purpose of the PAM-AID walker is to help some physical or poor eyesight of patients walking. Due to the limits of physical strength and impaired vision, which largely limits the freedom of movement, the PAM-AID system provides a safer and more enjoyable experience for these patients. The robot adopted a handle as the man-machine interface, the handle is suitable for elderly and easy to use. The chassis has four wheels, two motor drive front, the two motor is mainly responsible for changing the wheel direction, does not provide power. The robot also has the navigation system, it can be in a certain range of sensors to avoid obstacles and effectively ensure the safety of users. (2) University of Virginia has designed MARC Smart Walker, which is a walking robot with three-wheel structure. The system has installed a force senor on the handle, which is used to detect the walking intention of user. The front wheel of MARC Smart walker is controlled by the steering gear, and the two auxiliary rear wheels are followed. In addition, the ultrasonic and infrared sensors are installed on the robot to collect the environmental road information and avoid obstacles. The robot is a passive robot, with the steering wheel can only control the direction of movement of the walker, but cannot provide the driving force. In addition, the robot adopts the method of shared control, adjust the user's control of the system by the comprehensive consideration of the user's walking intention and environmental information. (3) Shanghai Jiao Tong University has preliminary completed the prototype of smart robot. The smart robot have a steering handle which installed at the upper part of the vehicle body [1, 2]. User can use the handle to control the robot forward, turn left and right, brake, acceleration and other operations. Handrail button and the next crew communication is achieved by the relay, and then control the speed of the drive motor.

In the paper, the main research is to identify the control intention of user and determine the movement-mode of elderly-assistant & walking-assistant robot [3]. However, the traditional service robot cannot identify the intention of human and determine its movement-mode. So the traditional service robot may be unable to correctly control according to user's intention, then may do some wrong action. The elderly-assistant & walking-assistant robot is designed for the elderly and the disable, this is very dangerous for the user. So, how to identify the intention of the user and determine the movement-mode of the robot is an important problem. To solve this problem is the research goal of this paper. Therefore, we proposed a method of recognition to control the movement-mode of elderly-assistant & walking-assistant robot. In this method, the fuzzy control algorithm is used to process the data, and determine the movement-mode of the robot by fuzzy algorithm. Finally, the simulation results show that the fuzzy control algorithm can effectively control the movement-mode of the robot, and the user to manipulate the robot correctly.

2. Drive Control System

Elderly-assistant & walking-assistant robot is an intelligent service robot, it can be based on the user's intention to adjust the posture of the robot. The posture of robot includes the transition between the walking posture and the conveying posture, as well as the movement state under different gestures: the traveling speed and the traveling direction. The robot obtain the tactile signals by the tactile-slip sensor which installed on the handle of the robot. The signal processing system is used to process the signal, and then the processed signal data is identified. The robot determine the intention of user and identify the walking-mode. In the control process, the interaction between the robot and the people is a more important part. The reliability and accuracy of human-computer interaction directly determine the performance of the robot [4, 5]. In addition, because the robot is targeted for the elderly or disabled people, and their physical condition is weaker than ordinary people. Therefore, choosing the appropriate tactile-slip sensor directly determines the correctness and reliability of the collected signal data. In this paper, PVDF piezoelectric sensor is selected to collect the touch-slip signal of the user's hand, the corresponding tactile-slip signal acquisition and processing circuit is designed to process the signal. The block diagram of the whole system is shown in Fig. 1.

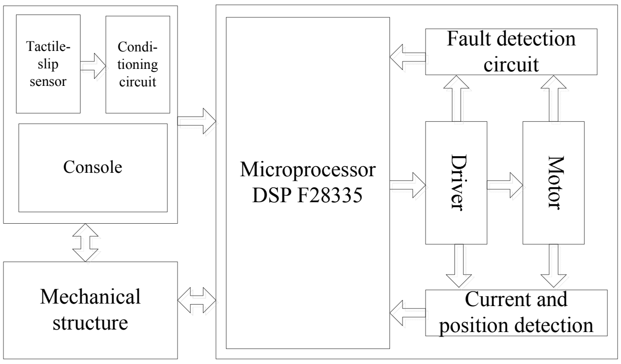

Fig. 1. Drive control system.

The position of the sensor is determined after taking into account the physical condition and manipulation of the elderly and the disabled. The tactile-slip sensor array is placed on the handle of the robot, which contact with the user's hand. The tactile-slip signal is collected by the tactile-slip sensor which placed at the handle, and the signal is processed by the signal conditioning circuit [6, 7]. Then, the walking-mode of the robot is determined by the pattern recognition module. In the next, the control information is sent to the auxiliary partner drive control system to control the motor. Finally complete the control process of the elderly-assistant & walking-assistant robot. The system uses the microprocessor DSP F28335 to process the data and control the brushless DC motor. The system controls the traveling direction and speed of the robot in accordance with the determined walking-mode of the robot.

3. Driving Signal Collection

The tactile-slip signal of the user's hand is collected by the tactile-slip sensor which installed in the handle of elderly-assistant & walking-assistant robot [3]. Each handle has a four-way tactile-slip signal collection module. Tactile-slip senor installation location shown in Fig. 2. The tactile-slip sensor made of PVDF piezoelectric film was placed on the front and back sides of the handle level on the ground. Each handle to install four-way tactile-slip sensor, a total of eight-way signal.

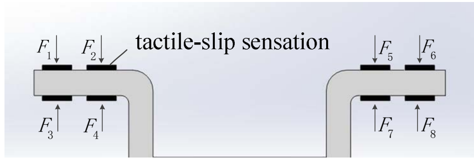

Fig. 2. Tactile-slip sensor array.

When the human hand contacts the PVDF piezoelectric film sensor, the PVDF piezoelectric film sensor generates the corresponding electrical signal, and the corresponding voltage value is obtained by filtering and amplification process. The resulting analog signal is subjected to AD conversion via DSP to obtain the corresponding pressure value. The size of the pressure represents, to a certain extent, the user's control intent, and when the user presses the handle with greater force, it is desirable that the robot be able to move at a faster rate. According to the tactile-slip signal to calculate the pressure value (F_1, F_2, F_3, F_4, F_5, F_6,F_7,F_8), and then calculated to be used for the subsequent fuzzy control algorithm. First, the average value of the unilateral pressure is calculated, and the pressure values in the direction are added to obtain the value after the fusion. The formula is as shown in Equation (1) and Equation (2).

$$F_L = \frac{(F_3 + F_4)}{2} - \frac{(F_1 + F_2)}{2} \quad (1)$$

$$F_R = \frac{(F_7 + F_8)}{2} - \frac{(F_5 + F_6)}{2} \quad (2)$$

The tactile-slip sensor, which is placed on the front of the handle, collects the force that the user pulls backwards relative to the robot, to a certain extent, the user wants the robot to slow down or move backward. And the force on the back of the handle is the user's thrust relative to the robot, indicating that the user wants the robot to accelerate or move forward, while the left and right handle under the combined action of the control robot to complete such as forward, backward, steering and other actions.

4. Fuzzy Inference

4.1 Fuzzy Control Algorithm

In the process of controlling the elderly-assistant & walking-assistant robot. After the signal acquisition process. How to judge the user's intention according to the tactile-slip signal and determine the movement-mode of the robot directly determines whether it can effectively control the robot to achieve the user's control requirements. Therefore, it is necessary to select a simple, effective and reliable control algorithm to determine the movement-mode of the robot. After studying various control algorithms, this paper proposes a fuzzy control algorithm to control the movement-mode of the robot [9, 10]. The basic structure of the fuzzy algorithm is shown in Fig. 3.

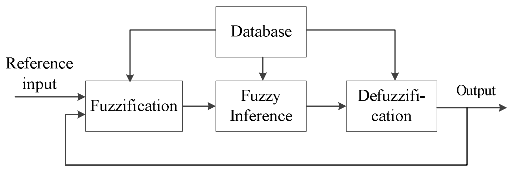

Fig. 3. The basic structure of the fuzzy algorithm.

A. Fuzzification

The function of this part is to transform the input quantity by fuzzification. Inputs quantity include external reference input and system output or status. The specific process of fuzzification: First, the input quantity needs to be processed. For example, calculate $e = r - y$ and $\dot{e} = de/dt$. Where r represents the reference input, y represents the system output, and e represents the error. Then the processed input will be scale transformed. To transform them into their respective domain. Finally, fuzzing the input value of the domain, so that the original precise input into a fuzzy amount, and set the corresponding fuzzy value to represent the input value.

B. Rule library

The knowledge base contains knowledge of specific areas of application and required control objectives. Usually represented by a database and a fuzzy control rule base. The database includes the membership function of each language variable, the scale transformation factor and the number of fuzzy spaces. The rule base includes a series of control rules that are represented by fuzzy language variables.

C. Fuzzy inference

Fuzzy inference is the most important part of fuzzy control. It is also the core of the fuzzy controller, which has the ability to simulate people's reasoning based on fuzzy theory. The reasoning process is based on fuzzy relation and reasoning rules in fuzzy logic.

D. Clarity

The result of fuzzy inference is a fuzzy quantity. The effect of clarity is to process the fuzzy quantity and convert the fuzzy quantity into a clear value that is used for actually control. First, the fuzzy quantity is convert to the clear value which in the domain. And then the clear value is to be scale transform to the value for actual control.

4.2 Fuzzy Inference Model

The above is the basic principle and structure of the fuzzy recognition. In the process of designing the walking-mode recognition system of the elderly-assistant & walking-assistant robot. The value f of the force and the rate of change $\dot{f}$ of the force are chosen as the input of fuzzy inference, the force is collected by the tactile-slip senor [11, 12]. And the output is the incremental speed Δv of the motor. Then define the corresponding fuzzy set, identify the variable domain, and establish the library of fuzzy rules. In this paper, the theoretical fields of the fuzzy sets of the input quantities f , $\dot{f}$ and the output Δv are {-6, -5 , -4, -3, -2, -1, 0, 1, 2, 3,4, 5, 6), the language variables of input f are {NB, NM, NS, NZ, PZ, PS, PM, PB}, and the input variables $\dot{f}$ are {NB, NM, NS, ZE, PS, PM, PB}, and the output variables Δv are {NB, NM, NS, ZE, PS, PM, PB}. Establish the corresponding library of fuzzy rules (Table 1).

Table. 1. The library of fuzzy rules.

$\dot{f}$ / Δv / f	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	ZE	ZE
NM	NB	NB	NB	NB	NM	ZE	ZE
NS	NM	NM	NM	NM	ZE	PS	PS
NZ	NM	NM	NS	ZE	PS	PM	PM
PZ	NM	NM	NS	ZE	PS	PM	PM
PS	NS	NS	ZE	PM	PM	PM	PM
PM	ZE	ZE	PM	PB	PB	PB	PB
PB	ZE	ZE	PM	PB	PB	PB	PB

The speed of the left and right motors obtained by the reasoning of the fuzzy reasoning module is taken as the reference value of the motor speed to control the motor. The specific control of the motor is realized by the differential steering system based on PID control. The control command is input to the motor drive controller according to the speed reference value, and the motor is controlled by drive controller. The control flow chart is shown in Fig. 4. Because this paper mainly verifies the feasibility of the fuzzy control theory in the robot control application, the PID regulation and the differential control of the motor are not detailed here.

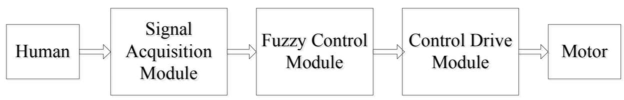

Fig. 4. The basic structure of the fuzzy algorithm.

5. Simulation analysis

In order to verify the feasibility of this method, MTALAB-Simulink is used to establish the system simulation test.

The fuzzy inference module is established by Fuzzy Toolbox. After setting the initial input signal and fuzzy reasoning database, two phase difference of 45 degrees sinusoidal signal is chosen to simulate the size of the force, as shown in Fig. 5, so the surface viewer of the fuzzy inference is shown in Fig. 6 and Fig. 7.

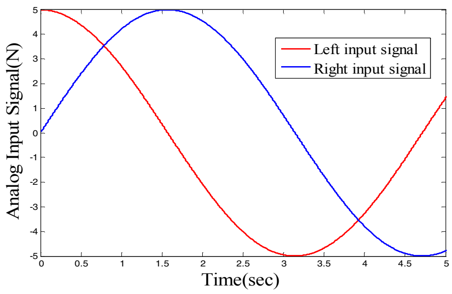

Fig. 5. Analog input signal.

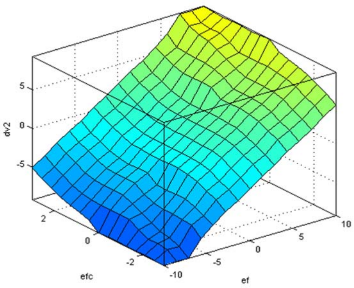

Fig. 6. Surface Viewer 1.

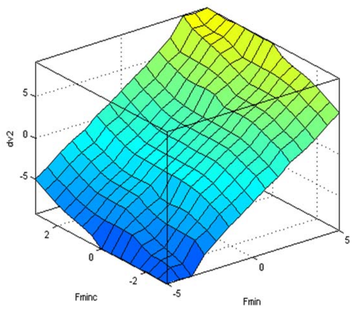

Fig. 7. Surface Viewer 2.

The output is shown in Fig. 8:

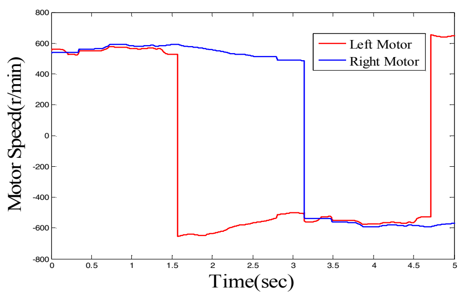

Fig. 8. Velocity increment.

Compared with the input signal, it is very clear that the output can effectively identify the walking-mode of the elderly-assistant & walking-assistant robot, including the direction and the velocity increment of the elderly-assistant & walking-assistant robot.

6. Conclusion

Fuzzy recognition algorithm can imitate human thinking to inference, including human experience and knowledge, so fuzzy algorithm is a kind of intelligent algorithm. The fuzzy recognition algorithm can meet the intelligent demand of the elderly-assistant & walking-assistant robot.

The simulation results show that the fuzzy recognition algorithm can effectively identify the walking mode of the robot. In addition, the simulation also verify the feasibility and reliability of the method. To ensure that the robot in the control process can be in accordance with the intention of user to move. The proposed fuzzy recognition algorithm has good adaptability and accuracy, so as to ensure the reliable operation of the elderly-assistant & walking-assistant robot.

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