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Description	



Development of an Easy-to-Manipulate Assistive Cart System Using an Observer Based Impedance Control

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Abstract - In this paper, we develop an assistive cart that allows users to transport heavy load with lower effort. Our focus is placed on how to design and control the assistive cart to provide reliable user-cart interactions regardless of the condition changes of the loaded weight and the ground. For this purpose, Force/Torque sensor and two motorized wheels are equipped on a conventional cart to response to the user's operation by sensing the input force and generating the assist force. The observer-based impedance control is designed to compute the assistive force with the input force of the user and the velocity of the cart. We verify the validity of the developed assistive cart by comparing the performance of the empty-cart case and the loaded-cart case.

Keywords - human-robot interaction, assistive cart, impedance control, force assist, easy maneuverability

1. Introduction

The elderly population is growing fast all over the world. More importantly, the proportion of the elderly workers in the fields of farming, fishing, and forestry has been increasing. As considering these situations, assistive devices to lighten their work burden are strongly desired. Typical examples include powered exoskeletons, powered wheelchairs and bicycles, and robotic carts. Among them, the robotic carts aim at helping users transport heavy objects easily and efficiently. The robotic carts have emerged with similar mechanical structures to conventional carts, but mechanical and/or electronic components are installed to promote power assist. Moreover, it is essential to secure reliable user-cart interactions regardless of disturbance changes such as loaded weight on the cart and friction between wheels and ground states.

In this paper, the main focus is how design and implement an assistive cart system to achieve easy yet reliable interactions between users and the robotic cart used in daily routines. For this, our solution approaches for the addressed problem are twofold. First, what is the most important aspect from the viewpoint of a hardware configuration is that an assistive module is designed and implemented as an interface unit in the robotic cart. Practically, the assistive module is composed of a 6-axis force/torque (F/T) sensor and two motorized wheels. The input force consisting of the direction and the magnitude is detected from the F/T sensor. Then, the motor generates a desired assist force which is computed with the sensed force and the velocity of the cart. Secondly, a disturbance observer based impedance controller is de-



Fig. 1 JAIST assistive cart

signed. Here, the impedance controller administers the assist force generated by differing between a user's input forces and the velocities of the assistive cart. Moreover, the disturbance observer updates the friction between the wheels and the ground. Therefore, the unknown parameters are estimated to provide idealized impedance between the input force and the cart defined as the condition of an empty cart.

2. System Description

The prototype of JAIST assistive cart is shown in Fig. 1. The handle part is modified to attach 6-axis F/T sensor [1] to measure the input force of the user. Two motorized wheel [2] is replaced at the rear wheels, respectively. The control box, which includes the motor controllers and power-supplies, are placed at the bottom of the cart. A laptop PC is used to read the measurement data from the sensors and write the assist force to the motor. In TABLE 1, the specification of the assist cart is expressed .

Table 1 Specification of JAIST assistive cart

Cart	Size	0.6×0.9	<i>m</i>
	Weight	27.0	<i>kg</i>
	Max. Speed	1.8	<i>m/s</i>
	Radius of wheel	130	<i>mm</i>
Motor	Power	150	<i>Watt</i>
	Voltage	24	<i>V</i>
Encoder	Counters/turn	500	<i>pulse</i>
Gear	Reduction	26 : 1	
F/T sensor	Maximum Load	200 – 3	<i>N – Nm</i>

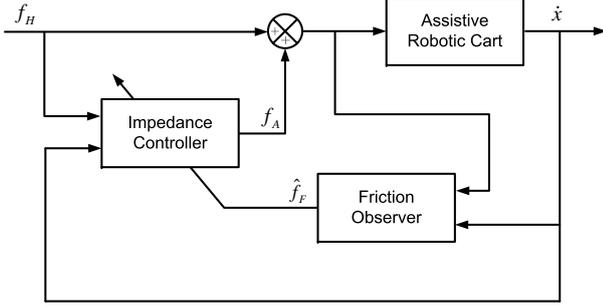


Fig. 2 Block diagram of observer-based impedance controller

3. Observer Based Impedance Controller

By considering the interaction force between user and assistive cart, we can compute the assist force to provide an experience that the user feels pushing an empty cart. The design controller structure is shown in Fig. 2. First, the assistive cart system is modeled as a single degree of freedom mass system which is operated by the input force of user f_H and the assist force of motor f_A as follows:

$$f_A + f_H = m\ddot{x} + b\dot{x} + f_F, \quad (1)$$

where x is the position of the cart, and m is the total mass of the cart and the additional weight. b is the damping coefficient at the wheel. f_F is the friction force. The desired interaction can be described as following equation based on the impedance model [3].

$$f_H = m_d\ddot{x} + b_d\dot{x} + f_{F_d}, \quad (2)$$

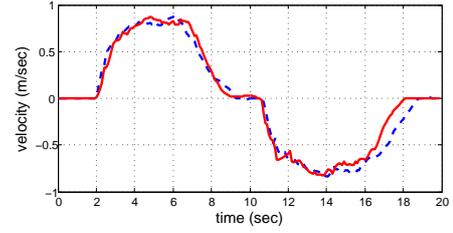
where m_d , b_d and f_{F_d} are the desired parameters for the desired interaction. In order to get the desired interaction characteristic, the desired acceleration is transformed from eq. (2) and substituted to eq. (1). Finally, the assist force should be give by

$$f_A = \left(\frac{m}{m_d} - 1 \right) (f_H - b\dot{x}) + f_F - \frac{m}{m_d} f_{F_d}. \quad (3)$$

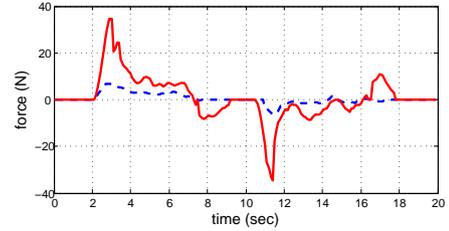
The friction observer is built based on the disturbance observer scheme [4] to estimate the unknown value, the current friction force in eq. (3).

4. Experimental Result

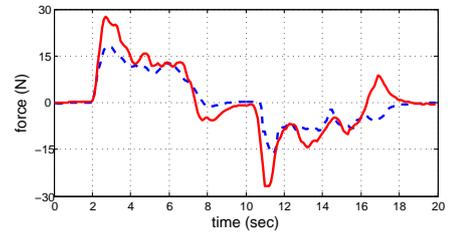
To verify and evaluate the developed assistive cart, extensive experiments are performed by a test-user. In Fig. 3, the velocity of the cart, the assist force and the user-input force are compared respectively between two load condition: without load or with 40kg load. The subject is instructed to operates the assistive cart forward and backward with similar velocity in two experiments as shown in Fig 3(a). In the loaded-case, the assistive cart generates more assist force to overcome the variance of the mass (Fig. 3(b)). In Fig. 3(c), the subject used similar force in the constant velocity period (4 – 6.5sec). However, more force is needed for the loaded cart in the acceleration (2 – 4sec).



(a)cart velocity



(b)assist-force



(c)user-force

Fig. 3 Results of experiments: without load case(dashed blue) Vs. 40kg-loaded case(solid red)

5. Conclusion and Future Direction

In this paper, an assistive robotic cart is developed to support the elderly worker. To satisfy this purpose, we upgrade the conventional cart with F/T sensor and two motorized wheels to measure the input-force of user and generate the assist force. The observer based impedance controller is designed to compute the assist force by using the impedance model which express the interaction between the user and the assistive cart. In the controller, the disturbance observer updates the friction between the wheels and the ground to the impedance controller. Experiments are conducted to demonstrate the feasibility of the integrated robotic cart. As a future works, several improvements will be considered to solve practical problems such as acceleration, rotation, and safety.

References

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