Passive-type Intelligent Walker Controlled Based on Caster-like Dynamics

Yasuhisa Hirata, Asami Muraki & Kazuhiro Kosuge
Department of Bioengineering and Robotics, Tohoku University
Japan

1. Introduction

With the coming of aging societies, many elderly people have serious problems for their locomotion, because of the decline of the physical strength for walking. If they could not use their legs for walking, their physical strength would be weak gradually and they could not walk finally without assistance of other people or some assist system such as wheel chairs, etc. The walking using legs of themselves is very important for improving the quality of their lives, even if they use several kinds of tools for walking such as cane, walker, etc.

In this paper, we pay attention to the walker which support the human based on the physical interaction between the human and the walker. The simple walkers, which consist of support frame, wheels/casters and hand-brakes, are used commercially in many fields such as home, hospital, outside, and so on. On the other hand, to develop the intelligent walkers, many researchers have been proposed several kinds of walkers. Manuel et al. have proposed non-holonomic navigation system of a walking-aid robot referred to as "Care-O-bot II" [1]. Savaniti et al. have developed the motorized "Rollator" [2]. Dubowsky et al. have proposed "PAMM" system to provide a mobility assistance and monitoring for the health status of the user [3]. Fujie et al. have developed the power assisted walker for physical support during walking [4]. We have developed the motion control algorithm of intelligent walker with omni-directional mobile base in which the system is moved based on the intentional force/moment applied by user [5]. Kotani et al. have also proposed "HITOMI" system for permitting outdoor navigation of blind people [6].

The most of the conventional intelligent walkers utilize the servo motors and control them by using the information of sensors such as force/torque sensor, ultra sonic sensor, laser range finder, and so on, to realize the several kinds of functions. Although the active-type walkers using servo motors could realize many functions such as collision avoidance, path following, variable motion characteristics, and so on for supporting the user, the safety issues of this active-type system should also be considered. If we can not control the servo motors of the active-type walker appropriately, the system would move unintentionally and be a dangerous system for human being. In addition, the active-type system might be heavy and its structure might be complicated, because it consists of servo motors, reduction gears, sensors, controller, batteries, and so on. The battery problem is also very severe for its long time working, because the servo motors need much electricity to work. Therefore, the active-type systems still have many problems for their practical use.

To overcome these problems, we have introduced a concept of the passive robotics, in which the systems are developed without using the actuators for mobility. Most of the conventional passive-type walkers based on the passive robotics controlled its heading direction by using the servo motors attached to a steering wheel which can not generate the driving force of walkers [7], [8]. In these systems, the navigation function using sensors such as ultra sonic sensor, laser range finder, etc. could be realized by controlling the steering wheel. Since these kinds of system cannot move by themselves, and can only move when the user applies the force/moment to it, it is intrinsically safe system to support the user in walking similar to the simple walkers which consist of support frame and wheels/casters.

We have also proposed a passive type walker referred to as RT Walker in [9]. Different from the conventional passive-type walkers, RT Walker dose not have servo motors for steering wheel. In stead of it, the servo brakes are attached to the wheels of RT Walker as shown in Figure 1, which can change the brake torques of rear wheels proportionally with respect to the input current. By changing the brake torques of wheels appropriately, the motion of RT Walker could be controlled based on a condition of user and/or environmental information. The brake system is very important and essential functions for most of walkers to adjust their speed from the safety point of view. The controlling of the brakes is effective for developing the intelligent walkers without attaching the active device like servo motors.

Different from the conventional passive-type walkers, RT Walker could realize not only the navigation functions but also its variable motion characteristics by controlling the servo brakes of wheels without using the servo motors [9]. In this paper, we especially propose a motion control algorithm of RT Walker based on the caster-like dynamics, so that the maneuverability of the RT Walker could be improved. In the following part of this paper, first, we introduce the concept of passive robotics and the passive-type intelligent walker referred to as RT Walker developed based on the passive robotics concept. Next, we explain the fundamental motion control algorithm of RT Walker briefly and extend it to the motion control algorithm based on the caster-like dynamics for improving its maneuverability. Finally, we implement its motion control algorithm in RT Walker and illustrate its validity through the experiments.

2. Passive Robotics

For utilizing the intelligent systems practically in the real world environment, we have to consider two points mainly. One is the high performance of them and the other is the safety for users. Most of the conventional intelligent systems have servo motors and they are controlled based on the sensory information such as the force/torque sensor, ultrasonic sensor, laser range finder, etc. Therefore, the high performances for intelligent systems are realized based on the many functions such as power assist, collision avoidance, navigation, variable motion characteristics, and so on.

However, if we can not control the servo motors of the intelligent systems appropriately, they would move unintentionally and be a dangerous system for human being. Especially, in Japan, the legislation has to be formulated for using them in a living environment practically. On the other hand, Goswami et al. have proposed a concept of the passive robotics [10], in which the system moves passively based on the external force/moment without using the actuators, and have dealt with the

passive wrist, whose components are springs, hydraulic cylinders, dampers, and so on. The passive wrist computes a particular motion in response to every applied force and changes the physical parameters of the components for realizing the desired motion.

A robot for direct physical interaction with a human operator within a shared workspace, referred to as COBOT, has been invented as an industrial application of the passive robotics especially for automobile industries [11]. A passive robot is intrinsically safe and its concept has been extended to many fields. PADyC, Passive Arm with Dynamic Constraints, has been proposed as an assistant tool for surgeons [12]. Other applications for surgical robots are seen in [13]. Applications to rehabilitation have been also considered by many researchers. One example is shown in [14]. Applications of the concept to haptic display have been proposed in [15], [16] etc.

In the fields of research on walker system, Wasson et al. [7] and Mac Namara et al. [8] have proposed passive-type intelligent walkers. In the most of them, the servo motor was attached to the steering wheel similar to Cobot system in order to control only the steering angle based on the information of an environment for navigating the user. RT Walker proposed in this paper also has a passive dynamics with respect to the force/moment applied to it. Different from the other passive-type walkers, RT Walker controls the servo brakes appropriately to realize the several functions without using any servo motors.

Many systems have been developed based on the concept of the passive robotics. These passive-type systems are intrinsically safe, since they do not move unintentionally. The passive robotics is a key concept when we consider real-world applications of the advanced robot technology.

3. RT Walker

The passive-type intelligent walker referred to as RT Walker developed based on the passive robotics concept is shown in Figure 1 (a). This prototype consists of a support frame, two passive casters, two wheels with powder brakes, laser range finders, tilt angle sensors, and controller. The part of the rear wheel with powder brake is shown in Figure 1 (b). The powder brakes can change the brake torques of rear wheels of RT Walker proportionally with respect to the input current as shown in Figure 1 (c) and they are transferred to the axes of wheels directly. RT Walker needs little electricity to work by using the servo brakes and is light weight, since its structure is relatively simple compared to the active-type walkers which utilize servo motors for controlling their motions.

By changing the brake torques of two rear wheels appropriately, the motion of RT Walker is controlled based on conditions of users. In addition, RT Walker could get environment information by using the laser range finder and the tilt angle sensors. Based on the information of the environment, RT Walker could realize a collision avoidance function, gravity compensation function, and so on.

In addition to the laser range finder for detecting the environment information, RT Walker has the other laser range finders for measuring the motion of the user, which is attached to the rear part of RT Walker. Based on the motion of the user, we could estimate the user state and change the several functions realized for the intelligent walkers [17].
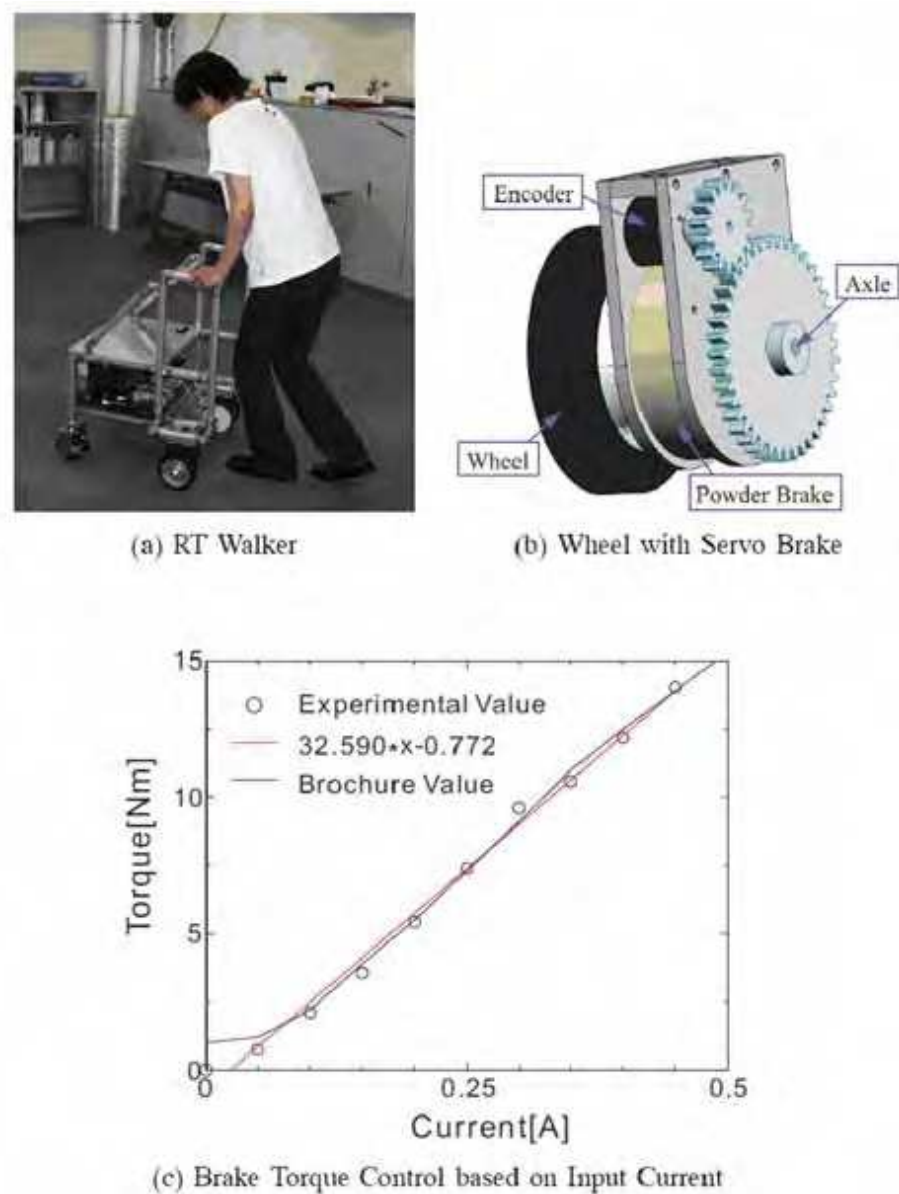
(a) RT Walker

(b) Wheel with Servo Brake

(c) Brake Torque Control based on Input Current

Fig. 1. Prototype of RT Walker.

4. Fundamental Motion Control Algorithm for RT Walker

First, we explain relationships among the brake torque, angular velocity, and applied torque of the wheel with servo brake for realizing the motion control of RT Walker. RT Walker can only move based on the external force/moment applied to it, because it does not have any actuators such as servo motors. To control the motion of RT Walker based on the external

force f_{ew} applied to the wheel with servo brake, we can derive the following relationships with respect to the angular velocity of the wheel with servo brakes ω_w.

for $\omega_w \neq 0$

$$t_{bw} = -k_b I_b \operatorname{sgn}(\omega_w) \tag{1}$$

for $\omega_w = 0$

$$t_{bw} = \begin{cases} -f_{ew} R_w & |f_{ew}| R_w \leq k_b I_b \\ -k_b I_b \operatorname{sgn}(f_{ew}) & |f_{ew}| R_w > k_b I_b \end{cases} \tag{2}$$

where t_{bw} is the brake torque generated by the servo brake of RT Walker, R_w is the radius of the wheel, I_b is the input current for the servo brakes, and k_b is the positive coefficient expressed the relationship between the brake torque and the input current. Different from the control of the servo motor, we can only control the motion of RT Walker under these relationships.

Next, we describe the fundamental motion control algorithm of RT Walker. Under the assumption that m_x and j_θ are the inertia coefficients, d_x and d_θ are the damping coefficients, and the velocity and the acceleration are defined as $\dot{x}$, $\dot{\theta}$ and $\ddot{x}$, $\ddot{\theta}$ respectively, the dynamics of RT Walker based on the force/moment f_h, n_h applied by the user and the brake force/moment f_h, n_h generated by the servo brakes is expressed as follows;

$$\begin{bmatrix} m_x & 0 \\ 0 & j_\theta \end{bmatrix} \begin{bmatrix} \ddot{x} \\ \ddot{\theta} \end{bmatrix} + \begin{bmatrix} d_x & 0 \\ 0 & d_\theta \end{bmatrix} \begin{bmatrix} \dot{x} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} f_h \\ n_h \end{bmatrix} - \begin{bmatrix} f_b \\ n_b \end{bmatrix} \tag{3}$$

where x-axis is defined as the heading direction of RT Walker as shwon in Figure 2, and the moment and the rotational motion expressed in eq.(3) are defined around the middle point of the real wheel axis.

In this research, the brake force/moment f_h, n_h generated by the powder brakes is controlled for realizing an arbitrary motion of RT Walker, and we can derive the brake torques t_{br}, t_{bl} of each wheel of RT Walker as follows;

$$\begin{bmatrix} t_{br} \\ t_{bl} \end{bmatrix} = \begin{bmatrix} R_w/2 & R_w/T \\ R_w/2 & -R_w/T \end{bmatrix} \begin{bmatrix} f_b \\ n_b \end{bmatrix} \tag{4}$$

where T express the distance between each wheel with powder brake.

For realizing the variable motion characteristics of RT Walker, we derive the following equation with respect to the brake force/moment;

$$\begin{bmatrix} f_b \\ n_b \end{bmatrix} = \begin{bmatrix} m_{dx} - m_x & 0 \\ 0 & j_{d\theta} - j_\theta \end{bmatrix} \begin{bmatrix} \ddot{x} \\ \ddot{\theta} \end{bmatrix} + \begin{bmatrix} d_{dx} - d_x & 0 \\ 0 & d_{d\theta} - d_\theta \end{bmatrix} \begin{bmatrix} \dot{x} \\ \dot{\theta} \end{bmatrix} \tag{5}$$

where m_{dx}, $j_{d\theta}$ are the apparent inertia of RT Walker and d_{dx}, $d_{d\theta}$ are the apparent damping. When we derive the brake force/moment from eq.(5), and specified the brake torques of the servo brakes of RT Walker as shown in eq.(4), RT Walker could move as if it has the following apparent dynamics expressed by m_{dx}, $j_{d\theta}$, d_{dx} and $d_{d\theta}$.

$$\begin{bmatrix} m_{dx} & 0 \\ 0 & j_{d\theta} \end{bmatrix} \begin{bmatrix} \ddot{x} \\ \ddot{\theta} \end{bmatrix} + \begin{bmatrix} d_{dx} & 0 \\ 0 & d_{d\theta} \end{bmatrix} \begin{bmatrix} \dot{x} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} f_h \\ n_h \end{bmatrix} \tag{6}$$

When we change the apparent dynamics of RT Walker using the brake system, we could realize many kinds of motion characteristics of RT Walker.

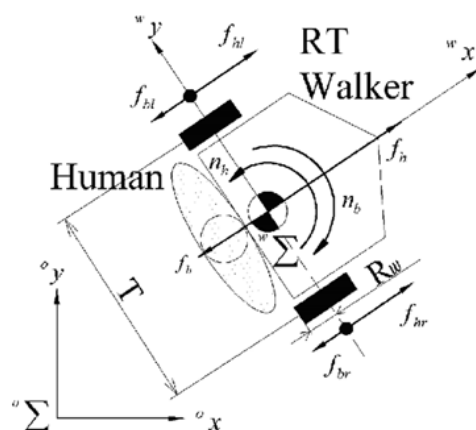Fig. 2. Model of RT Walker.

5. Caster-like Motion

5.1 Human/Environment-adaptive Motion Control

In the conventional control algorithm of RT Walker proposed in [9], we realize the human-adaptive and the environment-adaptive motion control algorithms. In the human-adaptive motion control algorithm, the apparent dynamics of RT Walker could be specified to it by controlling the servo brakes appropriately, so that we could change its maneuverability, which is explained briefly in the previous section.

However, we have not considered that how RT Walker change its apparent dynamics based on the condition of users, though we have proposed the method for changing the parameters of RT Walker. In this paper, we introduce an example of a method that how we change the apparent dynamics of RT Walker based on its condition, which could be realized by using the caster-like dynamics.

In the environment-adaptive motion control algorithm proposed in [9], we realize the collision avoidance motion of RT Walker using the laser range finder. In this algorithm, to derive the brake torques of servo brakes for avoiding the obstacles, we utilize the method based on an artificial potential field proposed in [18], which is generally utilized by the research of the mobile robot system.

For intelligent walkers, this method is very effective to realize the collision avoidance motion. However, when we consider that intelligent walker utilize in the real world environment including doors, elevators, shelves, walls, and so on, we could not utilize it easily, unless we recognize the object in the real world environment. For example, if RT Walker could not recognize a door, an elevator, a shelf and so on, we could not close to them by using RT Walker implemented in the general collision avoidance methods, because these kinds of object are regarded as obstacles.

To overcome these problems, in this paper, we propose a motion control algorithm based on the caster-like dynamics. By considering the caster-like motion and extending its motion to

the advanced motion characteristics of the caster, we could improve the maneuverability of RT Walker in the human-adaptive and the environment-adaptive motion control algorithms.

5.2 Caster-like Dynamics

The concept of the motion control of the robot based on the caster-like dynamics have been proposed in [19] for realizing the coordinative transportation of an object by using multiple mobile robots. In the algorithm proposed in [19], each mobile robot is controlled as if it has a caster-like dynamics as shown in Figure 3, and transports a single object together with other robots based on a intentional force/moment applied by a human. When the human applies the force/moment to the object, the wheel of each virtual caster rotates around the free rotational joint to the direction of the force applied by the human, so that the human could handle a single object together with multiple mobile robots. The caster-like dynamics is also robust against the inevitable positioning error of each robot, even if each robot has a slippage between the wheels of each mobile robot and the ground.

Intelligent walker realizes the physical interaction between the user and walker based on the force/moment applied by the user similar to the case of cooperative transportation of an object by a human and robots. In addition, the robustness with respect to the slippage between wheels of walker and the ground is required. In this paper, we extend the caster-like dynamics proposed in [19] and propose the control algorithm of RT Walker based on its caster-like dynamics for supporting the people who have walking difficulties.

In this section, we consider how the apparent dynamics of RT Walker are changed based on the condition of users or information of an environment. To realize the walker with good maneuverability, we propose Adaptive Caster Action in this paper, which is a control algorithm based on the caster-like dynamics. To realize the caster-like dynamics for RT Walker, first, we consider a motion of a real caster as shown in Figure 3.

The real caster consists of a wheel, a free rotational joint and a wheel support, which connects the wheel and the free rotational joint as shown in Figure 3. The motion of the caster is characterized by three kinds of motion. One is the translational motion of the wheel along the heading direction of its wheel, second one is the rotational motion of the wheel around a point where the wheel contacts with a ground, and third one is the rotational motion of the free rotational joint around its own.
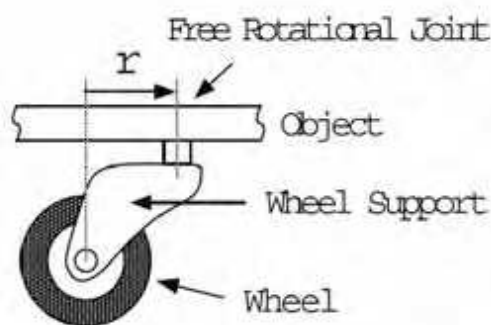

Fig. 3. Real Caster.

In this paper, we control the middle point of the axis of the rear wheels of RT Walker so as to have virtual caster wheel, and the virtual free joint is designed in the forward of RT

Walker along its heading direction as shown in Figure 4. To discuss the motion of the virtual caster, we define two coordinate systems as shown in Figure 4; a wheel coordinate system $^w\Sigma$ and a free rotational joint coordinate system $^f\Sigma$. $^w\Sigma$ is fixed on the virtual caster wheel, and $^f\Sigma$ is fixed on the virtual free rotational joint. The direction of x-axes of the wheel coordinate system and the free rotational joint coordinate system are defined as the heading direction of the virtual caster wheel as shown in Figure 4. The x-axis of the free rotational joint coordinate system is also defined as the heading direction of RT Walker.
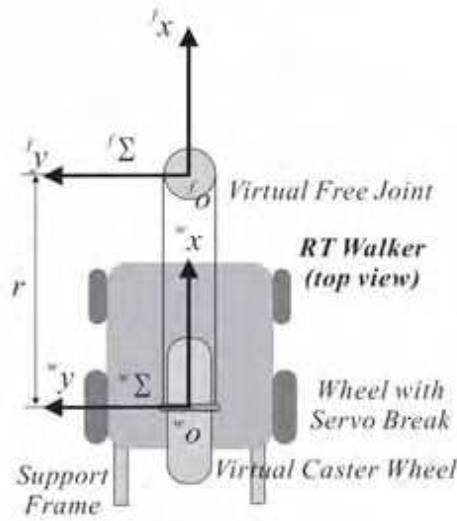

Fig. 4. Coordinate System of RT Walker.

To realize the caster-like dynamics based on two coordinate systems, first, we consider the translational motion of the virtual caster wheel around the free rotational joint based on the force applied to RT Walker along its heading direction as follows;

$$^f f_{hx} = {^f m_x} \, {^f\ddot{x}} + {^f d_x} \, {^f\dot{x}} \tag{7}$$

where $^f m_x$, $^f d_x$ are positive inertia and damping coefficients and $^f\ddot{x}$, $^f\dot{x}$ are acceleration and velocity of virtual caster wheel with respect to the free rotational joint coordinate system. $^f f_{hx}$ is a force applied to x-axis of the free rotational joint coordinate system by the human.

Next, to mimic the rotational motion of the caster wheel around a point where the caster wheel contacts with a ground based on the force applied to the virtual free rotational joint perpendicular to the heading direction of RT Walker, we obtain the dynamics of the free rotational joint using the following equation;

$$^f f_{hy} = {^f m_y} \, {^f\ddot{y}} + {^f d_y} \, {^f\dot{y}} \tag{8}$$

where $^f m_y$, $^f d_y$ are positive inertia and damping coefficients and $^f\ddot{y}$, $^f\dot{y}$ are acceleration and velocity of virtual free rotational joint. $^f f_{hy}$ is a force applied to y-axis of the free rotational joint coordinate system.

Actually, RT Walker is controlled around the middle of the axis of rear wheels of it, around which the virtual caster wheel is designed, based on the force/moment applied by the user. Therefore, we should derive the dynamics of the virtual caster with respect to the wheel coordinate system. When ${}^{w}f_x$, ${}^{w}n_\theta$, ${}^{w}\ddot{x}$, ${}^{w}\ddot{\theta}$, ${}^{w}\dot{x}$ and ${}^{w}\dot{\theta}$ are force/moment, accelerations, and velocities of the wheel coordinate system, the relations between the force, accelerations and velocities with respect to the free rotational joint coordinate system and the force/moment, accelerations and the velocities with respect to the wheel coordinate system are expressed as follows;

$${}^{w}f_h = {}^{f}f_{hx}, \quad {}^{w}n_h = {}^{f}f_{hy}r \tag{9}$$

$${}^{w}\ddot{x} = {}^{f}\ddot{x}, \quad {}^{w}\ddot{\theta} = \frac{{}^{f}\ddot{y}}{r} \tag{10}$$

$${}^{w}\dot{x} = {}^{f}\dot{x}, \quad {}^{w}\dot{\theta} = \frac{{}^{f}\dot{y}}{r} \tag{11}$$

where r is a offset of the virtual caster which is the distance between the virtual caste wheel and the free rotational joint as shown in Figure 4.

From eq.(9)-(11), the caster-like dynamics expressed in eq.(7) and (8) are modified as follows;

$$\begin{bmatrix} {}^{w}m_x & 0 \\ 0 & {}^{w}j_\theta \end{bmatrix} \begin{bmatrix} {}^{w}\ddot{x} \\ {}^{w}\ddot{\theta} \end{bmatrix} + \begin{bmatrix} {}^{w}d_x & 0 \\ 0 & {}^{w}d_\theta \end{bmatrix} \begin{bmatrix} {}^{w}\dot{x} \\ {}^{w}\dot{\theta} \end{bmatrix} = \begin{bmatrix} {}^{w}f_h \\ {}^{w}n_h \end{bmatrix} \tag{12}$$

where

$${}^{w}m_x = {}^{f}m_x, \quad {}^{w}d_x = {}^{f}d_x \tag{13}$$

$${}^{w}j_\theta = r^2 \, {}^{f}m_y, \quad {}^{w}d_\theta = r^2 \, {}^{f}d_y \tag{14}$$

This equation is similar to eq.(6), so that we could realize the caster-like dynamics by controlling the brake torques of wheels using the method explained in the previous section. It should be noted that we do not consider the rotational motion of the free rotational joint of the real caster around its own for implementing the virtual caster, because it dose not effect to the motion of RT Walker actually.

5.3 Adaptive Caster Action

In this section, we consider the maneuverability of RT Walker and propose a control algorithm referred to as Adaptive Caster Action for utilizing it effectively. The apparent dynamics of RT Walker is determined by control parameters such as inertia and damping properties, or offset of virtual caster. Especially, the apparent dynamics is strongly affected by the caster offset r. Adaptive Caster Action adjusts the caster offset based on the condition of users or information of environments

5.3.1 Human-adaptive Control

When the offset is large, the angular acceleration and the velocity of the wheel coordinate system are small as shown in eq.(14) and Figure 5 (a). The larger offset will stabilize the straight line motion of RT Walker against disturbance force perpendicular to the motion direction, but it will make the motion direction change difficult. On the contrary, when the offset is small as shown in Figure 5 (b), the wheel coordinate system rotates to the direction

of the intentional force easily, so that RT Walker could rotate to the intentional direction of user.
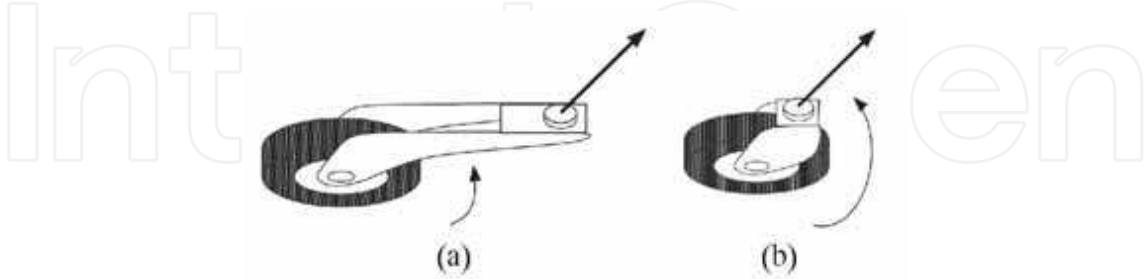

Fig. 5. Adaptive Caster Action.

Let us consider an example of Adaptive Caster Action based on the velocity of RT Walker along its heading direction. When a user moves in narrow space by using RT Walker, its velocity would be low and its easy rotation would be effective. In this case, the smaller caster offset is selected. On the other hand, when the user walks a long distance by using RT Walker, its velocity would be high and the straight line motion of RT Walker would be useful during the walking. In this case, the large caster offset is selected, so that the straight line motion is stabilized and the user could use RT Walker stably, even if the user applies the disturbance force to RT Walker by stumbling. To select the caster offset automatically based on these situations, we change the caster offset according to the velocity of the heading direction of RT Walker, which is expressed by the following equation as an example.

$$r = 0.6\sin(^{w}\dot{x}) + 0.2 \quad (^{w}\dot{x} \geq 0) \tag{15}$$

$$r = -0.2 \quad (^{w}\dot{x} < 0) \tag{16}$$

5.3.2 Environment-adaptive Control
To apply the adaptive caster action to the environment-adaptive motion control, we modify eq.(7), (8) as follows;

$$^{f}f_{hx} - {}^{f}f_{vx} = {}^{f}m_{x}{}^{f}\ddot{x} + {}^{f}d_{x}{}^{f}\dot{x} \tag{17}$$

$$^{f}f_{hy} - {}^{f}f_{vy} = {}^{f}m_{y}{}^{f}\ddot{y} + {}^{f}d_{y}{}^{f}\dot{y} \tag{18}$$

where ${}^{f}f_{vx}$, ${}^{f}f_{vy}$ are the virtual forces generated based on the information of an environment. By deriving the virtual forces based on the distance between obstacles/steps and the system appropriately and generate the brakes torques by using its virtual force/moment, a user could avoid the collision with obstacles or prevent missing his/her steps in a difference in level [9]. We utilize the method referred to as artificial potential field proposed by Khatib in [18], which is utilized generally in the research on the collision avoidance of the mobile robot.

For measuring the distance between the system and the obstacles or between the system and steps to derive the artificial potential field in the environment, in this research, we utilize the laser range finder which is attached to RT Walker with an angle with respect to the horizontal plan as shown in Figure 6. By attaching the laser range finder with the angle with respect to the horizontal plan, RT Walker could detect the positions of both the obstacles and the steps based on the measured distance.

If the distance is constant d_H, which is derived in advance based on the attached angle and height of the laser range finder from the ground level, this constant measurement means that RT Walker is on the flat ground without obstacles and the steps. When the measured distance is smaller than the constant distance d_H, RT Walker detect the obstacles. In this case, the virtual force/moment is derived based on the measured length d_O, so that the obstacle avoidance motion of RT Walker could be realized. If the measured distance is larger than d_H, RT Walker could detect the steps. In this case, RT Walker generates the map information based on the boundary position of the difference in level, because the length d_S does not change after the detecting the edge of the steps different from the detection of the obstacles. By deriving the virtual force/moment based on the map, the user using RT Walker could avoid the missing his/her steps.

As shown in eq.(17), (18), the virtual force is applied to the free rotational joint of the virtual caster. When we utilize the Adaptive Caster Action, the position of the free joint is changed based on the velocity of RT Walker as shown in Figure 7. When the velocity of RT Walker is high, the larger offset is selected. In this case, RT Walker is influenced by the virtual forces and the avoiding motions with respect to the collision with obstacles and the falling down from the steps could be realized.

On the other hand, when the velocity of RT Walker is low, the smaller offset is selected. In this case, RT Walker would not be influenced by the virtual forces compared with the larger caster offset, so that RT Walker could close to a door, a elevator, a shelf and so on. Even if RT Walker collides with the obstacles with low speed, the dangerousness would also be reduced. It should be noted that the falling down from the step is dangerous situations compared with the collision with obstacles. If RT Walker detects the steps, the control parameters of Adaptive Caster Action should be changed to prevent the falling accident.

6. Experiments

In this research, we implemented Adaptive Caster Action in RT Walker and did several experiments to illustrate the validity of the proposed control algorithm. In this experiment, we move RT Walker to the wall by pushing based on the different kinds of force as shown in Figure 8, so that RT walker closes to the wall in the different kinds of velocity. Motion paths of RT Walker with high speed and low speed are shown in Figure 9 (a), and velocity, caster offset, brake force/moment based on the Adaptive Caster Action during experiments are shown in Figure 9 (b), (c), (d) and (e) respectively.

From these experiments, you can see that RT Walker generates the collision avoiding motion based on the larger caster offset, when its velocity is high. On the other hand, RT Walker can close to the wall, when its velocity is low based on the smaller caster offset. By using Adaptive Caster Action, we could change the apparent dynamics of RT Walker based on its velocity, so that we could use it with good maneuverability in the real world environment.

7. Conclusion

In this paper, we introduce the concept of the passive robotics and the passive-type intelligent walker referred to as RT Walker developed based on the passive robotics concept. For improving the maneuverability of the walker in an environment such as a home, an

office, a hospital, etc., we proposed a motion control algorithm referred to as Adaptive Caster Action. The proposed control algorithm is experimentally applied to the developed RT Walker, and the validity of the proposed control algorithm was illustrated by the experimental results.
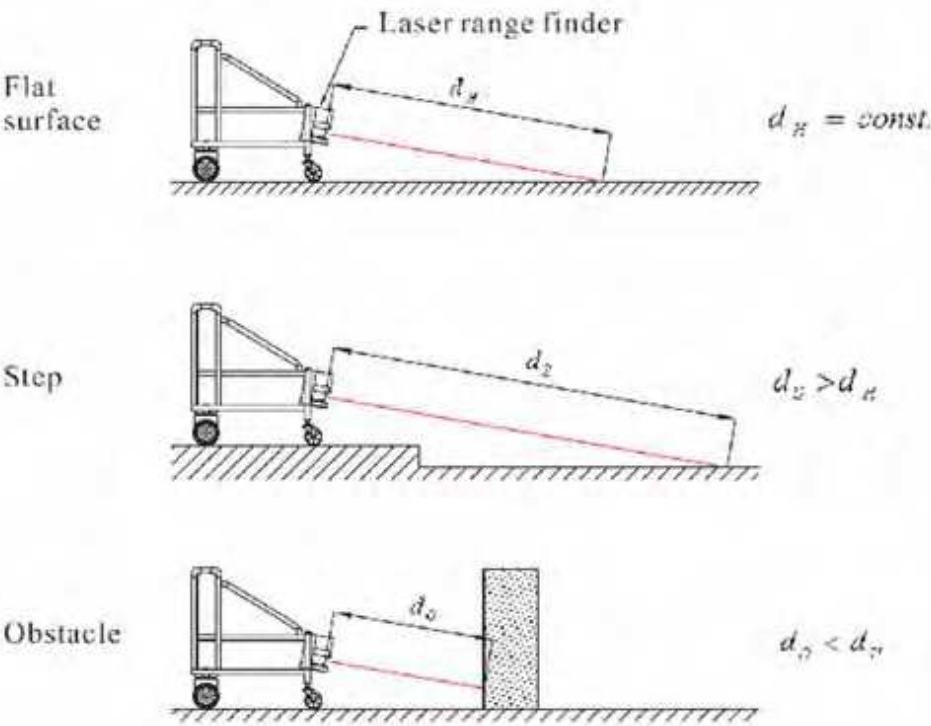

Fig. 6. Detection of Step and Obstacle using Laser Range Finder.
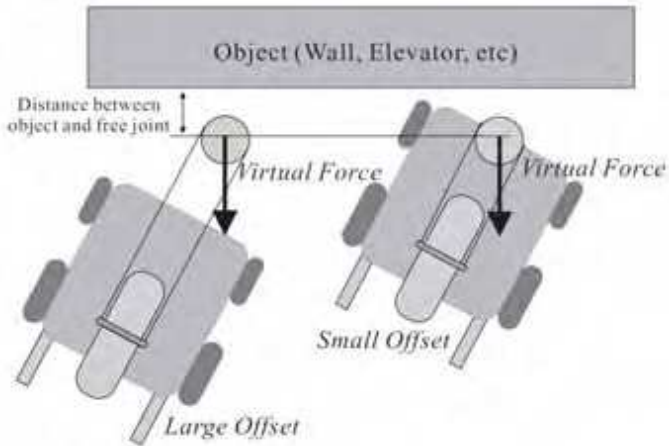

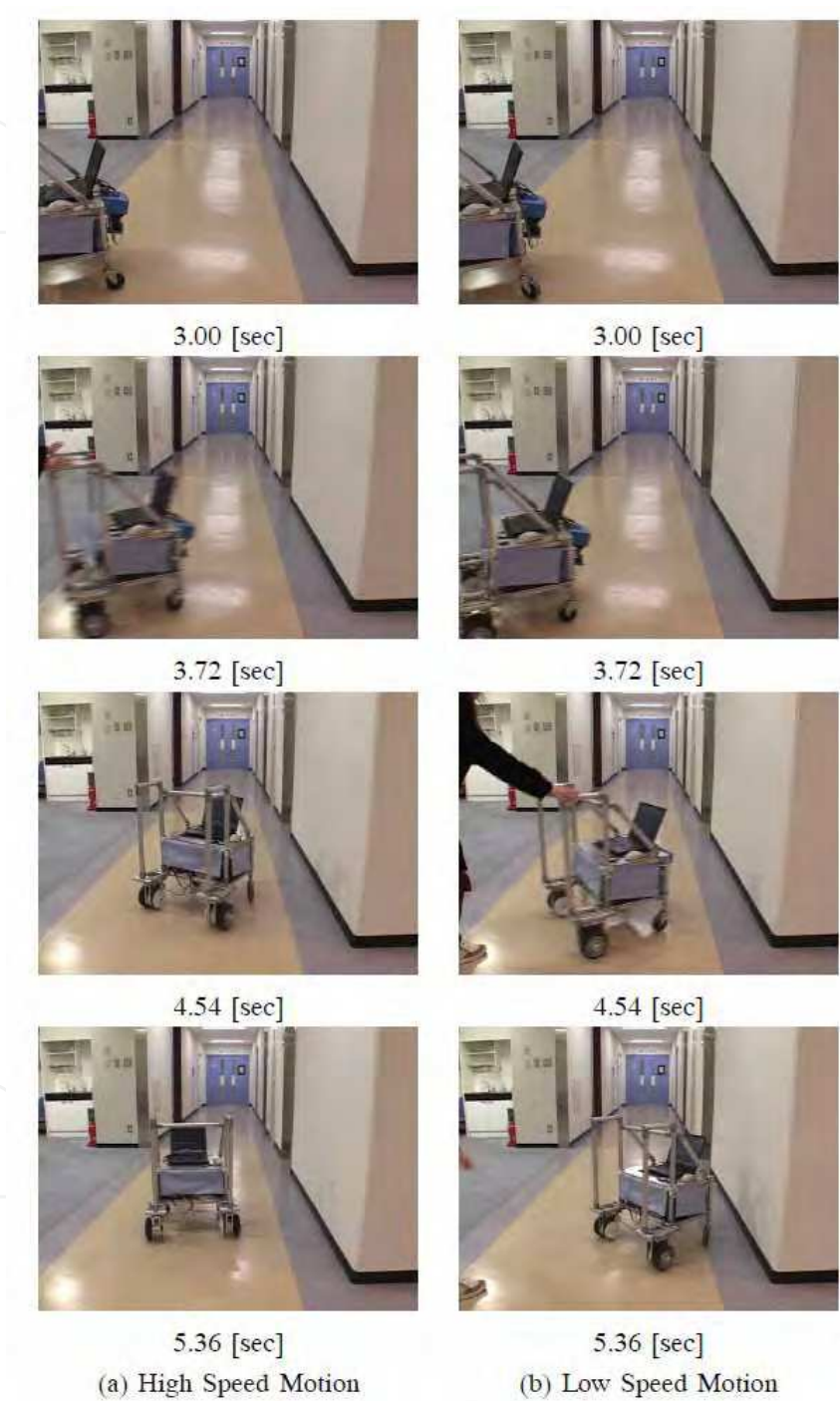Fig. 7. Environment-adaptive Motion Based on Adaptive Caster Action.

3.00 [sec]　　　　　　　3.00 [sec]

3.72 [sec]　　　　　　　3.72 [sec]

4.54 [sec]　　　　　　　4.54 [sec]

5.36 [sec]　　　　　　　5.36 [sec]

(a) High Speed Motion　　　(b) Low Speed Motion

Fig. 8. Motion of RT Walker Based on Adaptive Caster Action.

(a) Motion Path of RT Walker

(b) Velocity of Heading Direction

(c) Caster Offset

(d) Brake Force

(e) Brake Moment
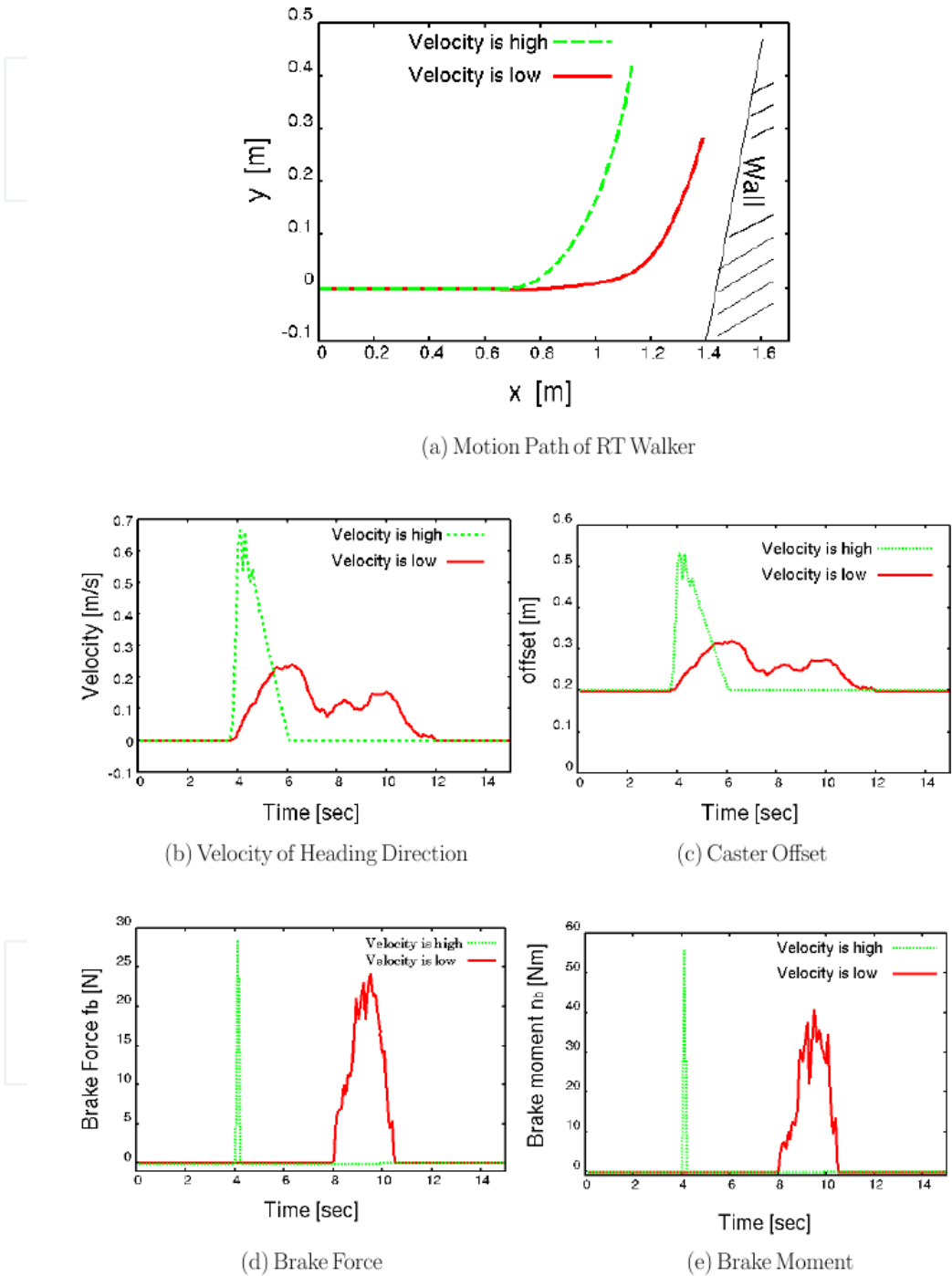
Fig. 9. Experimental Results.

8. Reference

[1]   J. Manuel, H. Wandosell, B. Graf, "Non-Holonomic Navigation System of a walking-Aid Robot", Proc. of IEEE International Workshop on Robot and Human Interactive Communication, pp.518-523, 2002.

[2]   A. M. Sabatini, V. Genovese, E. Pacchierotti, "Mobility Aid for the Support to Walking and Object Transportation of People with Motor Impairments", Proc. of IEEE/RSJ International Conference on Intelligent Robots and Systems, pp.1349-1354, 2002.

[3]   S. Dubowsky, F. Genot, S Godding, H. Kozono, A. Skwersky, H. Yu, L. S. Yu, "PAMM-A Robotic Aid to the Elderly for Mobility Assistance and Monioring: A "Helping-Hand" for the Elderly", Proc. of IEEE International Conference on Robotics and Automation, pp.570-576, 2000.

[4]   M. Fujie, Y. Nemoto, S. Egawa, A. Sakai, S. Hattori, A.Koseki, T. Ishii, "Power Assisted Walking Support and Walk Rehabilitation", Proc. of 1st International Workshop on Humanoid and Human Friendly Robotics, 1998.

[5]   Y. Hirata, T. Baba, K. Kosuge, "Motion Control of Omni-directional type Walking Support System "Walking Helper"", Proc. of IEEE Workshop on Robot and Human Interactive Communication, 2A5, 2003

[6]   S. Kotani, H. Mori, N. Kyohiro, "Development of the robotic travel aid HITOMI", Proc. of IEEE Int. Conf. on Robotics and Automation, 1990

[7]   G. Wasson, P. Sheth, M. Alwan, K. Granata, A. Ledoux, C. Huang, "User Intent in a Shared Control Framework for Pedestrian Mobility Aids", Proc. of the 2003 IEEE/RSJ Intl. Conf. on Intelligent Robots and Systems, 2003

[8]   A. J. Rentschler, R. A. Cooper, B. Blaschm M. L. Boninger, "Intelligent walkers for the elderly : Performance and safety testing of VA-PAMAID robotic walker", Journal of Rehabilitation Research and Development, Vol. 40, No. 5, 2003

[9]   Y. Hirata, A. Hara, K.Kosuge, "Passive-type Intelligent Walking Support System "RT Walker", Proceedings of the 2004 IEEE/RSJ International Conference on Intelligent Robots and Systems, (2004), pp.3871-3876, 2004.

[10]   A. Goswami, M. A. Peshkin, J. Colgate, "Passive robotics: an exploration of mechanical computation (invited) ", Proc. of the IEEE Int. Conf. on Robotics and Automation, pp. 279-284, 1990.

[11]   M. A. Peshkin, J. E. Colgate, W. Wannasuphoprasit, C. A. Moore, R. B. Gillespie, P.Akella, "Cobot Architecture", IEEE Transactions on Robotics and Automation, Vol. 17, No.4, 2001

[12]   O.Schneider, T.Troccaz, O.Chavanon and D.Blin, "PADyC: a Synergistic Robot for Cardiac Puncturing", Proceedings of 2000 IEEE International Conference on Robotics and Auotmation, 2000.

[13]   Jocelyne Troccaz, Peter Berkelman, Philippe Cinquin, Adriana Vilchis-Gonzales, "Surgical robot dependability: propositions and examples", 2nd IARP/IEEE-RAS Joint Workshop on Technical Challenge for Dependable Robots in Human Environments, 2002.

[14]   J. Furusho, M. Sakaguchi and N. Takesue: Basic Study for Development of Muscular-Strength Estimation and Training System Using ER Brake --- Development of ER Brake and its Passive Velocity Control---, Journal of RSJ, Vol.20, No.1, pp.77-84 (2002), in Japanese.

[15]   Michael A. Peshkin, J. Edward Colgate, Carl Moore, "Passive Robots and Haptic Displays based on Nonholonomic Elements", Proceedings of the 1996 IEEE International Conference on Robotics and Automation, pp.551-556, 1996

[16]   Michael A. Peshkin, J. Edward Colgate, Carl Moore, "Passive Robots and Haptic Displays based on Nonholonomic Elements", Proceedings of the 1996 IEEE International Conference on Robotics and Automation, pp.551-556, 1996

[17]   Y. Hirata, A. Muraki, K. Kosuge, "Motion Control of Intelligent Passive-type Walker for Fall-prevention Function based on Estimation of User State", Proceedings of the 2006 IEEE International Conference on Robotics and Automation,(2006),3498-3503

[18]   Y. Hirata, K. Kosuge, "Distributed Robot Helpers Handling a Single Object in Cooperation with a Human", Proc. of IEEE International Conference on Robotics and Automation, pp.458-463, 2000.

[19]   O. Khatib, "Real-Time Obstacle Avoidance for Manipulators and Mobile Robots", Int. Journal of Robotics Research, pp. 90--98, 1986.

Rehabilitation Robotics

Edited by Sashi S Kommu

The coupling of several areas of the medical field with recent advances in robotic systems has seen a paradigm shift in our approach to selected sectors of medical care, especially over the last decade. Rehabilitation medicine is one such area. The development of advanced robotic systems has ushered with it an exponential number of trials and experiments aimed at optimising restoration of quality of life to those who are physically debilitated. Despite these developments, there remains a paucity in the presentation of these advances in the form of a comprehensive tool. This book was written to present the most recent advances in rehabilitation robotics known to date from the perspective of some of the leading experts in the field and presents an interesting array of developments put into 33 comprehensive chapters. The chapters are presented in a way that the reader will get a seamless impression of the current concepts of optimal modes of both experimental and ap- plicable roles of robotic devices.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

INTECH
open science | open minds