Personal Mobility with Assistive Walker
User Interface Design for Vehicle Mode

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Abstract: This paper presents Personal Mobility with assistive Walker (PM-W). PM-W is consists of handle, handle post, position adjustable saddle, and two inwheel motors. The feature of PM-W is two mobile modes: ”walking assist mode” and ”vehicle mode”. In ”walking assist mode”, PM-W assists user’s walking by driving two wheels while user saddles on the seat and walks. In ”vehicle mode”, user controls PM-W like an electric bike or conventional senior cart. Thus, a certain control interface is needed in ”vehicle mode”. Therefore, this paper develops the interface for ”vehicle mode”. The proposed interface uses the bending strain at the root of the handle post, because the handle should not have any moving parts on it such as throttle lever or stick controller for supporting elderly’s stable posture. In order to verify the operability of this interface, the basic experiment was conducted. From the results of the experiment, it is appropriate that the interface is adopted for ”vehicle mode”, because it can be regarded that the operability of proposed interface is equal to or more than the conventional interface.

1 INTRODUCTION

It is important to take a customary exercise for keeping and promoting elderly’s health (Penedo, 2005). In particular, the activities with going out leads to maintain both mental and physical health (Transportation Research Board, 2005). However, there is the fact that the weak of elderly’s physical ability makes the range of activity narrow (Chou CH, 2012). Therefore, it is desired that a certain support system expanding the activity range with controlling the physical weakness. There are some solutions for this problem. Honda Walking Assist (Honda Motor Co., LTD., 2017) assists to keep the user’s walking rhythm and stride by power assisting for the swing of the legs while measuring the hip joint movement. This system enables user’s walking, however it requires pre-settings or preparation for walking because this is the wearable power assists device. The other walking support system is the electric cart with pedaling unit (Jinhua She, 2013). The feature of the system is the pedal unit which is the user interface of the electric cart, which is one of the Personal Mobilities, and it is able to control the load of it with adjusting user’s physical conditions. The rotational speed of the pedal is used for controlling the velocity of the cart. User can take exercise while moving by actuating the pedal. In addition, this system adopts the electric cart being kinds of personal motilities. Thus it can expand the activity range more than actual user physical ability, and can contribute to promote the activities with going out. However, the exercise in this system is different movement from natural human walking because it is only legs movements. It, therefore, is difficult to take whole body exercise like human walking. And walking exercise is recommended for keeping elderlies health (American College of Sports Medicine, 2009).

On the other hand, the walker with a saddle such as ”Raku-walk” (Kikuchi Seisakusho Co., LTD., 2017), ”AR-5” (Ai Label Co., LTD., 2017) and ”KW200” (Kishi Engineering Co., LTD., 2017) have been developed. These walkers do not use any actuators. The saddle in the walker partially supports user’s weight, user can move forward by moving their legs with sitting on it. Therefore it is expected to expand the user’s activities range with reducing physical load, because the leg strength is made full use for moving forward not for supporting their weight. However, it is difficult to realize natural walking, be-

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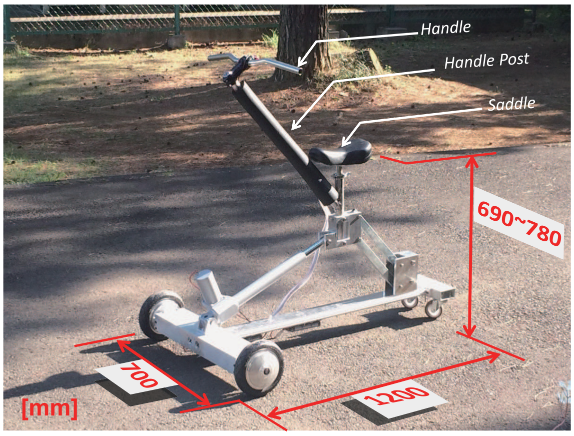

Figure 1: Overview of the PM-W.

cause user's pelvis leans during walking and sitting on these walking apparatus. It is also difficult to make an active power assist and remarkable expansion of activity range, because they do not have any actuators.

For this problem, we think that the problem can be solved by compensating each weak points in above mentioned walker and electric cart by combining the electric mobile function of PM and walker's exercise function. This research, therefore, proposes "Personal mobility with assistive walker: PM-W" which has two mobile modes being "walking assist mods" and "vehicle mode". Here, "walking assist mode" assists user's walking exercise, and "Vehicle mode" offers driving electric cart experience for users. In particular, this paper introduces the designed prototype of PM-W and studies the interface in the "vehicle mode".

2 OVERVIEW OF PM-W

The prototype of PM-W is shown in Fig. 1. PM-W is consists of handle, handle post, position adjustable saddle, and two inwheel motors. And PM-W is conventional two wheeled system shown in Fig. 2. In this figure, W[m] means width of PM-W and R[m] is radius of wheel. The control inputs of the system are Velecity v_{ref}[m/s] and angular velocity ω_{ref}[rad/s], and relationship between the wheel rotational speeds ω_r, ω_l[rad/s] and control inputs are designed by (1)(2).

$$v_{ref} = \frac{R(\omega_l + \omega_r)}{2} \quad (1)$$

$$\omega_{ref} = \frac{R(\omega_r - \omega_l)}{2W} \quad (2)$$

From (1) and (2), wheel speeds realizing v_{ref}, ω_{ref} are described as:

$$\omega_r = \frac{v_{ref} + \omega_{ref} W}{R} \quad (3)$$

$$\omega_l = \frac{v_{ref} - \omega_{ref} W}{R}. \quad (4)$$

Thus, the role of the developed interface is to generate the control inputs v_{ref}, ω_{ref} from user's control intention, and transmits these inputs to the servo driver of PM-W. Here the specification of PM-W is summarized in Table. 1.

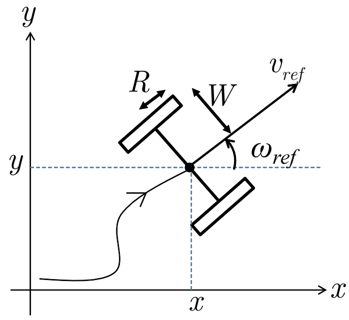

Figure 2: The coordinate system of the PM-W.

Table 1: Specifications of the PM-W.

Width	700 mm
Wheel Radius	4 inch
Weight capacity	80 kg
Actuator	DC brushless motor (90W x 2)
Power source	Ni-MH battery (22.2[V] 4.0[Ahr])

2.1 Two Mobile Modes

The feature of PM-W is that it has two mobile modes: "walking assist mode" and "vehicle mode" shown in Fig. 3.

(a) Walking Assists mode (b) Vehicle mode

Figure 3: Vehicle mode and Walking assist mode.

2.1.1 Walking Assist Mode

In "walking assists mode", the height of the saddle is adjusted to the user's hip position in an upright stance. The saddle partially support user's weight in the upright stance. User walks with grasping the handle. At this time, the handle functions as a handrail to support user posture not to fall down while walking. Here, the relative position of the saddle and the footrest was de-

designed so as not to inhibit natural user's walking by experimentally investigating the stride. Because there is a possibility of collision between the footrest and user's foots, if the relative position between saddle and footrest is not appropriately designed. In addition, the handle and handle post were rigidly mounted on the body frame of PM-W without any moving parts, because the handle is important part for user's safety for preventing from falling down. The system control the motor speed and assists user's walk with adapting users movements. In addition, by adjusting motor torque, the assists level can be adopted to user's physical ability. From the above, user can exercises while he/she moves with meeting own physical ability.

2.1.2 Vehicle Mode

In the "vehicle mode", the saddle position is lowered, and user completely sits on the saddle. Then user places own foots on the front section of PW-W as a foot rest. And user can move while two inwheel motors are controlled by the developed interface. By this mode, PM-W can be used as conventional electric cart, therefore, user can move and easily expand own activity range.

By switching above mentioned two mobile modes appropriately, user can exercise with moving and can expand own activity range.

2.2 Lifting Saddle Mechanism

The height of the saddle is different in these two modes. In the "Walking assist mode", the saddle position should be high and should have enough gap to foot rest depicted in Fig. 4 to realize natural walking. On the other hand, in "Vehicle mode", the saddle position should be low and close to foot rest. To do so, the saddle needs not only lifting function but also adjusting function in a back and forth position. In order to realize this movement by one actuator, the lifting and sliding mechanism using electric cylinder and parallel links is adopted shown in Fig.6. Thanks to this mechanism, the saddle can be adjusted in both height and back/forth position by one actuator.

3 USER INTERFACE FOR VEHICLE MODE

The general user interface represented by a stick controller or a throttle lever has the mechanical moving part, and user operates a machines by adjust its range.

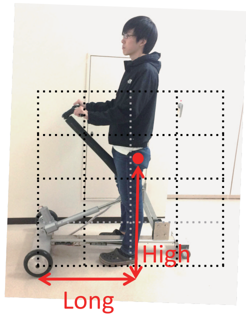

Figure 4: Saddle height at Walking Assist mode.

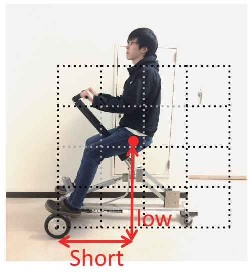

Figure 5: Saddle height at Vehicle mode.

Figure 6: Lifting saddle mechanism.

In our PM-W, the contacting point between user and the machine is the handle. Therefore the handle should also be utilized as the interface in "vehicle mode". However, the handle is used as a handrail for preventing from falling down or supporting elderlies stable posture. Thus, the handle should not have the moving part on it such as throttle lever or stick controller.

3.1 Input Information to Interface

When user grasps the handle and adds forces on it, the small strain occurs in the handle post (the handle is shown in Fig. 1). This system adopts the strains around the handle post as an interface inputs. By this method, it will be possible to obtain user's control intention form the rigid part.

3.2 FEM at Post of Handle Bar

In order to realize the interface using strains, the attaching portion of strain gauges is studied by Finite Element Method. The purpose of this FEM is as:

- Selection of the attaching part for controlling forward and backward movement of PM-W
- Selection of the attaching part for steering control of PM-W.

Here, there are two types of strain being bending and twisting. It is natural to use the vertical bending strain being generated when the user puts the handle in forward and backward for controlling forward and backward movements.

The candidates for steering control are following two parts:

- The bending strain in left and right direction, when user applies the forces on the handle in lateral direction to realize steering control of PM-W
- The twisting strain, when user twists handle to realize steering control of PM-W.

In these two strains, the part showing big strain is preferable to be used for inputs to the interface even if small forces are applied, because the resolution of control forces from user becomes high. For this reason, the part showing big strain is used for steering control of PM-W.

FEM is conducted under following conditions: the material handle post is aluminum A6063, the hollow pipe (inner diameter 24mm, outer diameter 28mm). the following three kinds of forces are applied to the handle.

FEM1 The bending strain when the forces are applied to the both endpoints of handle parallel to y axis in Fig. 7. (forward / backward operation)

FEM2 The bending strain when the forces are applied to the both endpoints of handle parallel to x axis in Fig. 8. (Steering operation)

FEM3 The twistin strain when the forces are applied to the both endpoints of handle parallel to y axis in Fig. 9 in oposit direction each other. (Steering operation)

The result of FEM1 is shown in 7. From this figure, it is turned out that vertical bending strain is generated at root of handle post by applying forward / backward forces to both endpoints of handle. Thus, the vertical strain at the root of the handle post can be used for forward / backward control of PM-W.

The result of FEM2 and FEM are shown in Fig. 8 and Fig. 9 respectively. Form these figures, it is turned out that both bending and twisting strain are generated at the root of the handle post. These strains are summarized in Table 2. In this table, FEM2 shows bigger strain than FEM3. From this thing, the horizontal bending strain is more suitable than twisting strain for the steering control of PM-W.

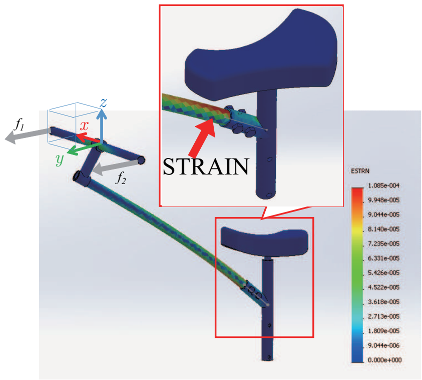

Figure 7: Bending strain at the root of handle post by forward force on the handle.

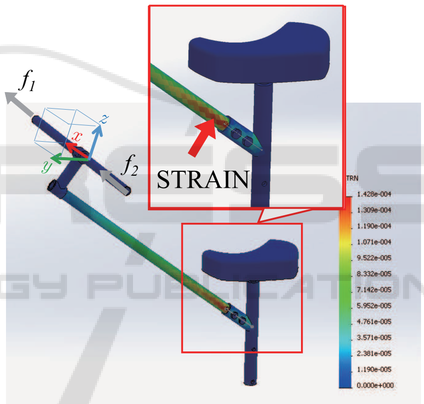

Figure 8: Bending strain at the root of handle post by lateral force on the handle.

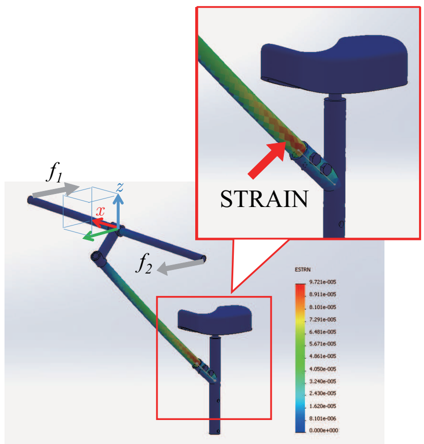

Figure 9: Bending strain at the root of handle post by twisting force on the handle.

Table 2: Rsults of FEMs.

	Drection of applied force	Strain
FEM1	Forward	1.09×19^{-4}
FEM2	Right	1.48×19^{-4}
FEM3	Twisting Right	9.72×19^{-5}

From the above, this system adopts the bending strains in horizontal and vertical direction at the root of handle post as the inputs for the interface in ”vehicle mode”.

3.3 Sequence of the Control

The vertical bending strain is used for forward / backward control. The horizontal bending strain is used for steering control. Here, the vertical strain is expressed by ε_v, and the horizontal strain is shown in ε_ω. The both initial strains are expressed by $\varepsilon_{v0}, \varepsilon_{\omega 0}$. The control inputs $v_{ref}\,\omega_{ref}$(1),(2) are generated based on these strain as follows:

$$\begin{pmatrix} v_{ref} \\ \omega_{ref} \end{pmatrix} = \begin{pmatrix} a_1 & 0 \\ 0 & a_2 \end{pmatrix} \begin{pmatrix} \varepsilon_v - \varepsilon_{v0} \\ \varepsilon_\omega - \varepsilon_{\omega 0} \end{pmatrix} \tag{5}$$

Here, a_1, a_2 are conversion coefficients from strain to control inputs, and their values are set by cut & try. The total system configuration including the interface is shown in Fig. 10. The bending strains at the root of the handle post are measured by the strain gauges, and measured strains are amplified and are sent to the Aruduino Mega. Aruduino Mega generates the control inputs v_{ref}, ω_{ref} by using (5), and calculates the each motor speed ω_r, ω_l by using (3) and (4). The motor drivers (Hibot, 1BLDC PowerModule©) receives ω_r, ω_l, and then the motors are driven and PM-W is activated. The open loop control is adopted for motors.

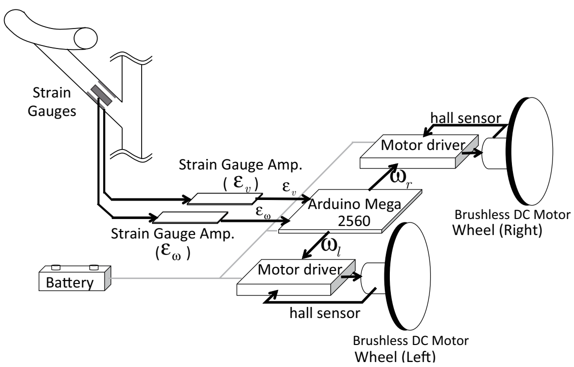

Figure 10: System configuration of the mobile platform.

4 TEST RUN

In the ”Vehicle mode”, since the interface using moving parts cannot be used for user safety, this system adopts the bending strains at the root of the handle post. In order to verify the operability of this interface, the basic experiment was conducted. In this experiment, we prepared the stick controller as the control to proposed interface. The stick controller is widely used for electric wheelchair and man-machine interface.

The subject operated PM-W by using two interfaces along with the course shown in Fig. 11. At that time, the lap times by two interfaces were measured. If the lap time by the proposed interface would be same as it by the stick controller, it could be said that the proposed interface has equivalent operability to the conventional interface.

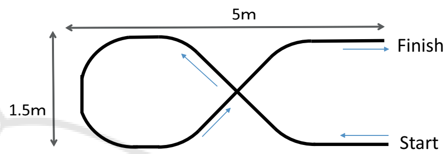

Figure 11: Shape of a course.

In this experiment, 10 subjects were recruited, their age are 20s. They were lectured on how to drive the PM-W in advance, and were given 3 minute practice for each interface. After that, the lap time was measured.

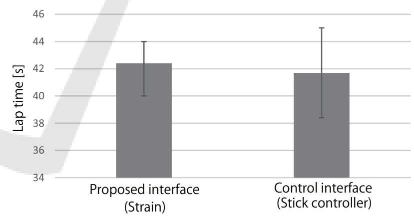

Figure 12: Lap time by Proposed and Control interface.

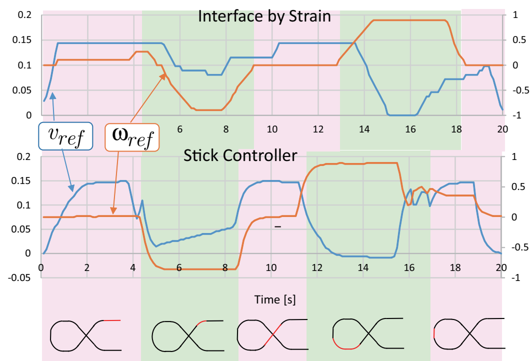

Figure 13: Transition of Control Inputs of both inputs.

Fig. 12 shows the average of lap time by each interface. t test of Fig. 12 shows $p = 0.17 > 0.05$, therefore there is no significant difference between two lap times. Thus, it can be said that proposed interface has equivalent operability to the conventional interface. In addition, let us focus on the transition of the control inputs during experiment in both interface shown in Fig. 13. From this figure, it is observed that the control inputs by the stick controller are oscillated while the control inputs by propose interface smoothly changed. From this oscillation, the stick controller needs fine correction operation. In particular, transition of v_{ref} is largely oscillated. This means the velocity of the PM-W is also oscillated. This kinds of motion cannot provide comfortable ride or easy operation.

Thus, from the viewpoints of lap time and smoothness of the control inputs, it is turned out that the proposed interface provides smooth operation compared to the conventional interface though there is no differences between the lap times by the proposed and conventional interface.

From the above, it is appropriate that the interface using strain at the root of handle post is adopted for ”vehicle mode”, because it can be regarded that the operability of proposed interface is equal to or more than the conventional interface.

5 CONCLUSION

This paper presented Personal Mobility with assistive Walker (PM-W). PM-W has two mobile modes: ”walking assist mode” and ”vehicle mode”. In ”walking assist mode”, PM-W assists user’s walking by driving two wheels while user saddles on the seat and walks. In ”vehicle mode”, user controls PM-W like an electric bike or conventional senior cart. Therefor a certain control interface is needed in ”vehicle mode”. Thus, this paper develops the interface for ”vehicle mode”.

The main contact point between user and PM-W is the handle. The handle is used as a handrail for elderlies safe in both modes. Therefore the handle should not have any moving parts on it such as throttle lever or stick controller. From this things, the bending strain at the root of the handle post is focused on for the interface. When user applies own forces to the handle, the handle post has a strain. In order to realize the interface using bending strain at the handle post, FEM was conducted to find the suitable strain part for the interface. As a result, the vertical and horizontal strain at the root of the handle post is used for the inputs of the interface. In order to verify the operability of this interface, the basic experiment was conducted. From the results of the experiment, it is appropriate that the interface using strain at the root of handle post is adopted for ”vehicle mode”, because it can be regarded that the operability of proposed interface is equal to or more than the conventional interface.

As the future works, we will develop the control scheme for walking assists mode including the stability of the user.

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