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Study on intelligent baby carriage with power assist system and comfortable basket †

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Abstract

In Japan, lightweight and easy-to-fold baby carriages are commonly used because a parent has to hold both the baby and its carriage while ascending or descending a flight of stairs. Since families commuting by private automobiles are increasing, there is a demand for carriages with high functionality. In this study, an intelligent baby carriage equipped with an advanced electro-hybrid power assist system that uses in-wheel-type motors is experimentally developed. This system assists the parent in lifting the carriage onto a sidewalk by detecting the edge of the sidewalk using an ultrasonic distance sensor. The carriage also has the following features: a tilt control system that keeps the basket in a horizontal position even on a slope, and a heartbeat simulator that provides comfort to the baby in the basket by simulating the heartbeat of the parent. The effectiveness of the proposed carriage is confirmed by performing experiments.

Keywords: Assist system; Comfort in riding; Heartbeat; Intelligent equipment; Motion control; Perambulator; Pram; Tilt control

1. Introduction

Most baby carriages belong either to the A-type (bed style) or the B-type (chair style). These carriages can easily be adjusted to suit the age and lifestyle of the baby. Although a few urban locations are adequately equipped to enable easy accessibility for baby carriages, there still exist many places such as the flight of stairs in a station or a pedestrian bridge, where it is difficult to move with baby carriages. In Japan, lightweight and easy-to-fold baby carriages are commonly used in view of the fact that a parent has to hold both the baby and its carriage while ascending or descending a flight of stairs, for example, at a station. On the other hand, the popularization of the automobile has increased the number of families that use a private automobile. Such parents lay more emphasis on the functionality of the baby carriage than its weight. Therefore, the author proposes an intelligent baby carriage that is equipped with an electro-hybrid power assist system consisting of in-wheel-type motors and a pendulum-type basket for passively reducing the pitch and roll angles while moving on a slope [1]. In this study, the A-type baby carriage is improvised in order to develop a novel carriage that is convenient for both the baby as well as the parent. While moving on a flat road or a slope, the in-wheel-type motors assist the parent in moving the carriage by making use of electric energy. The system also assists the parent in lifting the carriage onto a sidewalk by detecting the edge of the sidewalk using an ultrasonic distance sensor, controlling the velocity of the carriage, and applying a torque through the in-wheel-type motor to lift the front wheels. In addition, the carriage is equipped with a tilt control system that controls the pitch angle of the basket and keeps it in a horizontal position even on a slope. It is also equipped with a heartbeat simulator that generates weak shocks that simulate the heartbeat of the parent

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in order to comfort the baby when the basket is in a horizontal position. The effectiveness of this carriage is confirmed by performing experiments.

2. Design of the baby carriage

2.1 Arrangement of in-wheel-type motors

Using in-wheel-type motors for all the four wheels increases their adaptability because the driving energy is transmitted to the wheels by thin electric wires. In other words, the wheelbase and the tread of the wheels can be freely changed depending on the conditions of the road. However, if all the four wheels have motors, the carriage becomes heavy.

Driving the front wheels enables the carriage to be turned left or right by introducing a difference in the rotational speed between the left and right wheel. Moreover, front-wheel drive assists the baby carriage in climbing a step or a sidewalk whose height is lower than the radius of the wheel. However, the extra weight on the front wheels may make it difficult for the parent to handle the carriage by using the push bar installed at the rear of the carriage.

On the other hand, if the rear wheels are driven, the baby carriage cannot be made to turn by introducing a difference between the rotational speeds of the right and left wheels. In addition, a slight aid is required from the operator at the beginning of the turn. However, the application of the additional force can be recognized as a signal from the operator for turning. This action is suitable for the assist system. When the carriage is run up a sidewalk, the operator will find it easier to lift the front wheels in the case of a rear-wheel drive than in the case of the front-wheel drive. Therefore, taking into consideration these merits and demerits, in this study, the rear-wheel drive is adopted.

2.2 Support of the basket

When the basket is inclined on a slope, it becomes discomforting for the baby, especially when lying down. To prevent this, the intelligent baby carriage is equipped with a control system that keeps the basket in a horizontal position. In addition, for foolproofness, the basket is supported like a pendulum by using a linked pendulum mechanism to prevent it from tilting, which occurs when the basket is supported by pin joints, when the baby changes its position. To design the arrangement of links, the pitch angle when the basket is on a slope is simulated by using motion analysis software (MSC Software Co., MSC.visual-Nastran 4D). The simulated model of the linked pendulum mechanism is shown in Fig. 1. The upper box represents a basket that is 760 mm in length, 520 mm in width and 180 mm in height. The middle plates represent the support columns, and the lower plate represents the frame. The arrangement of the links shown in Fig. 1 is decided by trial and error under the condition that the basket pitch angle should be reduced to two-thirds of the slope angle. The performance of the carriage is then evaluated experimentally by lifting the front or rear wheels. The results are shown in Fig. 2. The pitch angle of the basket is reduced to approximately three-fourths of the frame pitch angle. Therefore, the failsafe performance of the linked pendulum mechanism is confirmed experimentally. The small magnitude of the decrease in the reducing of the pitch angle is due to the friction in the basket control system.

2.3 Trial production of baby carriage

On the basis of the above considerations, the baby carriage was developed on a trial basis by using aluminum pipes and plates. Fig. 3 shows the experimen-

Fig. 1. Simulation model of basket supported by linked pendulum mechanism.

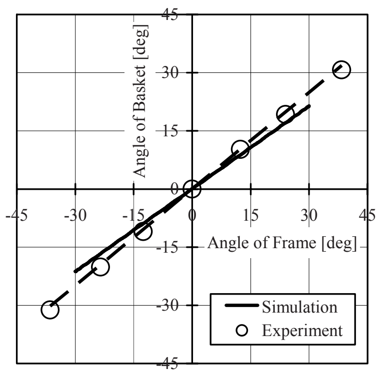

Fig. 2. Basket angle in case of frame tilting.

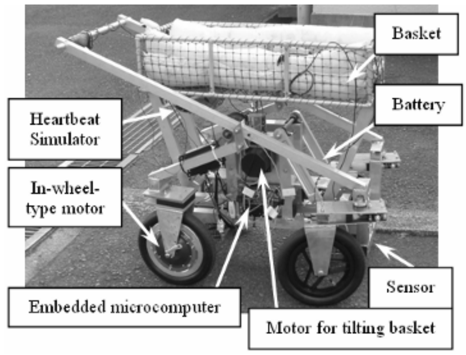

Fig. 3. Experimental prototype of the baby carriage.

tal prototype of the carriage. The total length of the carriage is 1100 mm, the tread is 480 mm, the wheelbase is 500 mm, and the diameter of the wheel is approximately 300 mm. The basket is supported by the linked pendulum mechanism and is tilted by a small geared motor controlled by an embedded microcomputer. For tilt control, an acceleration transducer is installed on the basket for sensing the basket pitch angle. Each rear wheel is equipped with an in-wheel-type motor that is controlled by a throttle grip, which is set on the push bar, through an embedded microcomputer. A one-way micro joystick is also set on the throttle grip for turning the carriage. An ultrasonic distance sensor is installed on the frame between the two front wheels for detecting the edge of a sidewalk. The power source is a lithium-ion battery used in electro-hybrid bicycles (or in electrical assist bicycles), and the battery is placed under the basket for balance. In addition, a heartbeat simulator is installed at the bottom of the basket to comfort the baby.

3. Intelligent system

3.1 Electro-hybrid power assist system

The electro-hybrid power assist system is one of the features of the proposed baby carriage. This system not only assists the carriage while moving on a flat road or a slope, but it also assists it in climbing onto a sidewalk.

3.1.1 Assist for climbing onto a sidewalk

A rapid rotation of the throttle grip enables the in-wheel-type motors to lift the front wheels. However, in the case of a low curb, the front wheels may unnecessarily rise much higher than the height of the curb and therefore generate a shock upon landing on the sidewalk. Since it is impossible for a human to

Fig. 4(a). The front wheels climbing up the curb.

Fig. 4(b). The carriage being driven until the rear wheels meet the curb.

Fig. 4(c). Rear wheels climbing up the curb.

finely operate the throttle according to the height of curb, an ultrasonic distance sensor is installed on the frame between the two front wheels to detect the edge of the curb and its height. Furthermore, a control system for lifting the front wheels onto the top of the curb is developed. The algorithm is designed as follows. First, the speed of the carriage is reduced as it approaches the edge of the curb; second, by rapidly rotating the throttle grip, the in-wheel-type motors are made to generate the large torque required to lift the front wheels. Third, in order to avoid the front wheels from rising higher than required, the torque applied is stopped as soon as the sensor fails to detect the edge of the curb, as shown in Fig. 4(a); fourth, the carriage is driven by motors until the rear wheels meet the curb, as shown in Fig. 4(b). Finally, the rear wheels are made to climb up the curb, as shown in Fig. 4(c).

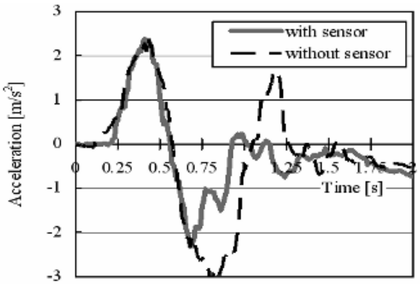

Fig. 5. Comparison of vertical acceleration of the frame near the front wheel with and without sensor.

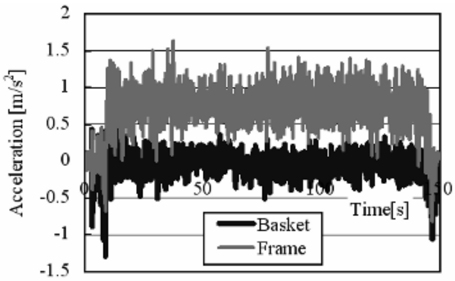

Fig. 6. Comparison of longitudinal accelerations of the basket and the frame of the carriage when ascending a slope.

The effectiveness of the control system has been experimentally confirmed. The vertical acceleration of the frame near the front left wheel is measured within an interval of 10 ms. The collected data are filtered with a moving average of 25 data points in order to remove the high-frequency component. Fig. 5 shows the time history when the front wheels climb onto the curb. For comparison, the vertical acceleration when not using the ultrasonic distance sensor is also shown in this figure. The bold line represents the case where the sensor is used, and the broken line represents the case where the sensor is not used. The first positive change in the acceleration in the Fig. corresponds to the front wheels being lifted up, and the following negative change and fluctuation correspond to the front wheels landing onto the sidewalk. When the sensor is used, the time for which the front wheels are lifted is shorter and the landing shock is smaller than for the case in which sensor is not used. Moreover, fluctuation of the vertical acceleration is immediately damped. Thus, the effectiveness of the control system is confirmed.

3.2 Tilt control system for basket

The tilt control system for the basket was developed to provide comfort for the baby in the basket. To maintain the basket in a horizontal position while ascending or descending a slope, the longitudinal acceleration of the basket is measured and nullified by the control system. It also prevents the baby in the basket from swaying due to sudden changes in the speed. The tilt control system works by lifting the rear and the front of the basket when the carriage accelerates and decelerates, respectively. Fig. 6 shows the time history of the longitudinal acceleration of the basket (bold line) and the frame (solid line) when the carriage ascends a slope with an inclination of about 5 degrees. Although the control system cannot respond effectively to rapid changes in the acceleration, it is confirmed that the acceleration of the basket along the slope is almost zero.

4. Simulation for comfort of the baby

The low-frequency sway and the high-frequency vibration of the carriage are reduced by the tilt control system and suspensions, respectively, thereby minimizing uncomfortable disturbances for the baby in the basket. In addition, the proposed baby carriage comes with a simulator that provides comfort for the baby. Generally, a baby stops crying when its mother hugs it. Although the smell, warmth, and the body shape, etc. of the mother could be the reasons for this, the rhythm of her heartbeat is the main reason. Therefore, the simulator installed at the bottom of the basket generates weak shocks that simulate the heartbeat of the operator, that is, the parent.

4.1 Ear sensor, heartbeat detector and simulator

An ear sensor resembling a small clothespin, shown in Fig. 7, that is worn on an earlobe is selected or sensing the heartbeat of the operator, because it disturbs the operator a little. This ear sensor is generfally used in an exercise bicycle (or an ergometer) at health clubs. The measured signal is amplified and converted into a digital TTL signal by the heartbeat detector. The signal is then transmitted to the heartbeat simulator by using a small-sized wireless transmitter and receiver. The detected heartbeat rhythm is then reproduced in the simulator shown in Fig. 8. To simulate the heartbeat, the simulator generates a shock by using a solenoid that pushes against a thin plastic plate covered by rubber. The solenoid operates according to the TTL signal.

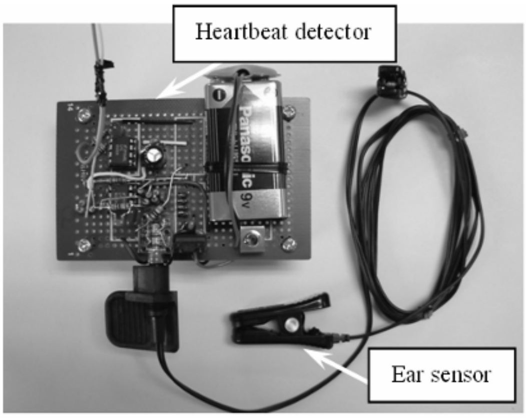

Fig. 7. Ear sensor and heartbeat detector.

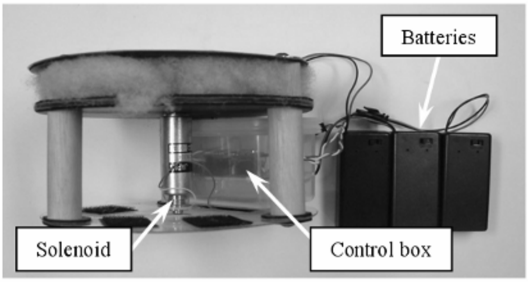

Fig. 8. Heartbeat simulator.

4.2 Effectiveness of the heartbeat simulator

The effectiveness of the heartbeat simulator has been confirmed by the author [2, 3]. Here, the experimental procedure and the results are explained. The examinee was a child playing with its grandmother in a nursery, and the observer was the child's mother in a room adjacent to the nursery. The heartbeat of the mother was measured and converted into a TTL signal by the heartbeat detector. This signal was transmitted to the heartbeat simulator through the Internet, and a wireless system. The simulator was set in a pillow, and the pillow was placed near the child. The child was observed by the mother via a video camera. The experimental devices are shown in Fig. 9.

Initially, the measured heartbeat of the mother was reproduced by the heartbeat simulator in the pillow for 17 min in order to accustom the child to the simulator. The simulator was stopped for 10 min, and subsequently, the heartbeat of the mother was once again reproduced for 10 min. Finally, a constant rhythm with a standard pulse rate of 1.3 Hz was reproduced for 10 min by a signal generator. Although the duration of simulation was told to the mother, the type of signal was not. The following data were obtained for the child.

Before the experiment. The responses given to the questionnaire by the mother indicate the child to be neither in a good mood nor in a bad mood. Further, they indicate the child to be a bit strained, excited, and sleepy.

(1) Mother's heartbeat I. Initially, the child did not respond to the sound simulated in the pillow. However, the child began to respond to the sound after a duration of 9 min. Then, the child touched the pillow by hand, confirmed the movement, and held it. The mother's responses to the questionnaire indicate that the child was in a peaceful state of mind, that it responded to the pillow, and that it began to like it. According to the mother, the child was initially afraid of the pillow but later developed an interest in it.

(2) No simulation. After 4 min, the stopping of the sound from the pillow was confirmed by the child, and the child was no longer interested in it. Responses to the questionnaire also indicate that the child was no longer interested in it. According to the mother, the child did not care about the pillow after the simulation from the pillow was stopped.

(3) Mother's heartbeat II. After the sound coming from the pillow resumed, the child began to take an interest in the pillow. The child then touched the pillow by hand and held it. The mother's responses to the questionnaire suggest that the child was in a peaceful state of mind, that it preferred holding the pillow, and enjoyed holding it. According to the mother, the child preferred the pillow and greatly enjoyed it after the sound resumed.

(4) Constant rhythm. The child did not take an interest in the pillow even when it was presented by its grandmother. Responses to the questionnaire indicate that the child did not take an interest in the pillow. According to the mother, the child did not take an interest in the pillow even after changing the simulation to the constant rhythm from the mother's heartbeat.

After the experiment. Responses to the questionnaire indicate that the child was in a good, relaxed, calm, and slightly active mood.

According to the mother, the conditions favorable for the child are in the following order: 3. Mother's

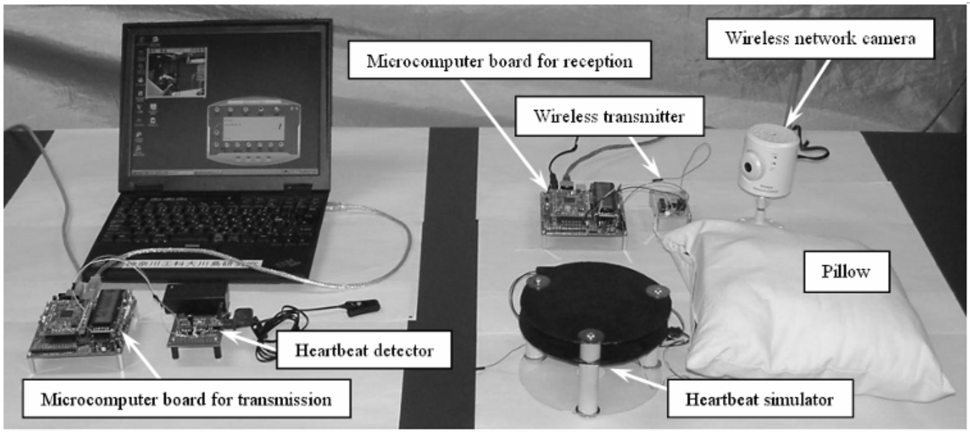

Fig. 9. Photograph of heartbeat transmitting system.

heartbeat II, 1. Mother's heartbeat I, 2. No simulation, and 4. Constant rhythm. The following inferences were drawn by the mother from the experiment. Although the child was reserved, she was easily accustomed to the sound of the pillow. From the response to the change from the simulation of the mother's heartbeat to the constant rhythm, it can be concluded that the child responded to the mother's heartbeat. Moreover, since the child was only two years old, the mother did not expect the child to respond to the pillow and was surprised by her child's interest in the pillow. From these results, although only one child was examined, the effectiveness of simulating the mother's heartbeat can be confirmed.

The author had previously developed a rocking chair that actively adjusts its swing according to the fluctuations in the heartbeat of the seated person. This study confirms one of the amazing applications of heartbeat simulation [4].

5. Conclusions

An intelligent baby carriage with an electro-hybrid power assist system using in-wheel-type motors, a tilt control system for the basket, and a heartbeat simulator for providing comfort to the baby has been experimentally developed. This novel carriage is useful for both the baby as well as its parent. The effectiveness of the proposed carriage has been experimentally confirmed.

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