ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 5, November 2012

Nursing-Care System for Bedridden Patients with Electric Wheelchair, Lift, Portable Bath, Mobile Robot and Portable Toilet

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Abstract*—A new type of assistance system that can support bedridden patients to reduce the burden of nursing care is described in this paper. The nursing of the bathing for the patients lying in the bed is one of the most serious work in the assistance. The proposed assistance system has several components. The first component is an multifunctional electric wheelchair that has the function as a portable bed by reclining the seat. The second component is a new type of lift for carrying a patient. Using this, caregiver can carry the patient from the wheelchair to the bath, or to a normal bed. The third component is a portable bathtub made from vinyl cloth and supported by an aluminum frame and that can be moved. Another challenging task for caregivers is helping patients with incontinence. As the fourth component of our system, we designed a cleaning mechanism for the portable toilet, with an autonomous control system. For the final component of our system, to help overcome this problem, we have designed a small mobile robot with a portable toilet to set up under the seat of the wheelchair. The robot can move inside the house after moving out from under the wheelchair. The proposed omni-directional mechanism allows the robot with the portable toilet to adjust not only to a narrow room such as a restroom but also to a narrow hallway.

***Index Terms*—Assisted Bathing, Bedridden Patients, Nursing Tasks, Portable Toilets.**

I. INTRODUCTION

Throughout the world, the senior population is forecasted to continue to increase in size. One person in five is currently a senior citizen in our country, sixty-five years old or older, and the estimation is that one in three persons will be a senior citizen by 2020. As shown in Fig. 1, it is also estimated that the ratio of senior citizens will exceed thirty percent of the whole by 2050 [1]. Clearly we must prepare for the increased burden on caregivers for this population in the future.

Generally, home nursing is expensive, and there are many procedures that need to be performed. When a family can take care of its elderly members, this helps with the burden, but family members frequently need the assistance of equipment such as wheelchairs and lifts. Whether it is the family or nursing professionals doing the work, frequent moving of patients between wheelchairs and beds, assistance with bathing, and help with excretion all take considerable time and energy. Thus, we propose a useful system that reduces the load of these nursing tasks. The system consists of a number of instruments. For the bath services provided by visiting nursing-care workers, it is known that the cost in a single visit is relatively high.

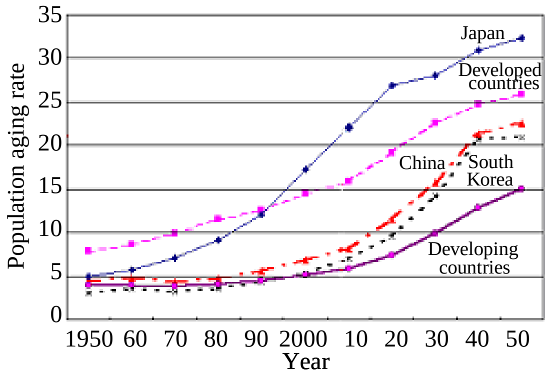

Fig. 1 Population Aging Rate

Normally, the patient spends the majority of his or her time in a wheelchair or on a bed, and excretion is challenging in this case. In response to this challenge, we propose a mobile robot with a portable toilet. Since this robot can be stored under the wheelchair, it is possible to excrete using the seat of a wheelchair instead of a toilet seat. After use, the robot moves to an ordinary permanent restroom in the home, where a mechanism above the toilet assists with disposing of the excrement and cleaning the toilet by flushing the water in the mobile robot. The purpose of the present study was to develop a robot to not only perform autonomous movement inside the house but also to clean itself automatically by exhausting sewage. We also developed a simple portable bathtub that can be set up in the living room or the bedroom. Furthermore we developed a manual lift that can transport patients between the portable bathtub, permanent bed, and a wheelchair. There was also a need to improve the wheelchair. A bedridden patient can be supported while reducing the load of nursing tasks by caregiver using this integrated system.

There have been many developments in wheelchair capabilities in recent years. Akishita [2] has realized a wheelchair that can move even in a narrow space. The wheelchair has a voice-operated mechanism that allows the seat to move up and down and back and forth and rotate in response to speech recognition. Yoneda [3] et al. have described the challenges of developing a robot that goes up and down the stairs. Wada et al. [4]-[6] have developed a wheelchair with omni-directional wheels and used it experimentally. Kitagawa [7] et al. have proposed a novel motion control method for an omni-directional wheelchair to suppress the vibration of both the wheelchair and the patient.

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Ikeda et al. [8] have proposed a cooperative strategy that enables both a wheelchair and a wheeled robot to climb a step by a simple link mechanism. Ohmura et al. [9] have proposed a wheelchair with a hinged caster that enables step climbing. Matsumoto [10] proposed a sensing system whereby the wheelchair uses laser viewfinder and map information to recognize its own position and the details of its environment. Ienaga et al. [11] have proposed an on-demand patient service system that uses RFID tags, and a wheelchair robot for use in medical facilities. They have structurized environmental information and constructed an in-hospital movement support system where information presentation and transportation are executed for the patients, the staff, and the robots. Mitani et al. [12] have evaluated the influence of visual blockage for wheelchair-bound individuals with visual disturbance based on the difference of the suspension existence.

II. NURSING-CARE SYSTEM

A concept chart of a patient's life in the case of using our proposed nursing-care system is shown in Fig. 2 ([13], [14]). The patient spends most of his or her time on a bed, or in an electric wheelchair in usual life (a). The patient can spend a lot of time during the day on the improved bed of the wheelchair, and can be moved even outside using the original function of the wheelchair by pushing the chair. The developed convertible wheelchair is effective for bedridden patients because the seat can be reclined fully to make a bed, allowing for short periods of sleep in the wheelchair. The manual lift is used to transport the patient between the bed, bathtub, and wheelchair (b). The caregiver moves the patient using the wheelchair, then reclines the seat of the wheelchair and uses the lift device and steering wheel to move the patient to the bed or bathtub. Lifting the patient with the manual lift device reduces the energy expenditure of the caregiver.

To support the excretion needs of the patient [15], the mobile robot with the portable toilet is placed under the wheelchair in the living room or the bedroom for use in place of the permanent restroom (c). Since it would not be good hygiene to let the portable toilet sit neglected after use, the mobile robot under the portable toilet moves to the nearest restroom (d), exhausts the waste, and flushes the toilet (e). The robot then returns to its station under the wheelchair. With this nursing-care system, the caregiver's workload is reduced considerably.

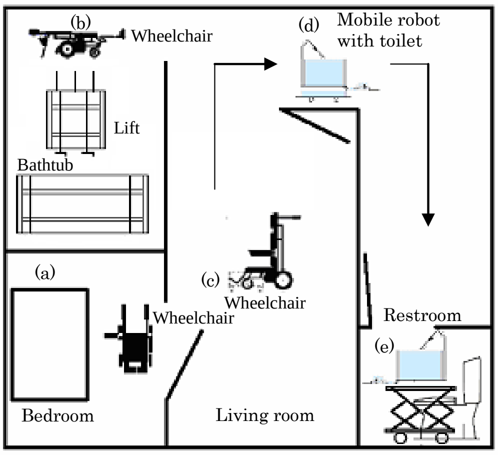

Fig. 2 Diagrammatic Illustration of the Nursing-Care System

A. Multi Functional Electric Wheelchair with Full Reclining

Here, we describe a new type of electric wheelchair which can support bedridden patients. The wheelchair used in this study was an electric wheelchair made by Kawamura Cycle Co., Ltd. (model KE15), shown in Fig. 3. A joystick controls the velocity, and the motor rated output is 192 W (24 V). The angle of the reclining (backrest) covers a range of 90-140° (Fig. 4(a), (b)). We develop a wheelchair equipped with a simple bed and a portable bath. To use this electric wheelchair as a portable bed, the angle θ at Fig. 4(c) is extended within the range of 90-180°. As shown in Fig. 4, the backrest consists of a parallel structure where links between points A and B comprise a gas spring damper. Changing both the angle range θ and the length AB can be accomplished using this gas spring. The rotation joints of a parallel link are found at points O, A, and B, respectively, and the difference between the expansion and contraction of the gas spring damper AB is given by ΔL. For the positions of arbitrary points A (x, y), minimum values ΔL of the difference between the expansion and contraction of the gas spring damper when θ was changed among 90-180° correspond to part of the valley in Fig. 5. If point A is selected again to reduce the distance between each segment on OB and point A, the difference ΔL between expansion and contraction becomes small, and then conversely, the range of the angle can be enhanced using the same gas spring.

Fig. 3 Electric Wheelchair

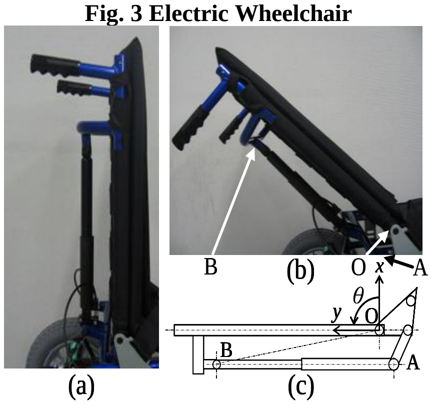

Fig. 4 Parallel Mechanism in the Wheelchair

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Next, four gate-legs, 300 mm long, are mounted on the sides of the wheelchair, and four polypropylene boards, 850 mm long by 265 mm wide by 36 mm thick, are attached to the gate-legs, so that the wheelchair can function as a portable bed (Fig. 6(a)). The boards can be cushioned with flexible material if desired (Fig. 6(b)). Fig. 6(c) shows the case where the gate-legs are installed on the right and left sides of the wheelchair. In this case, since the seat is not being extended, the purpose of the gate-legs is to support the weight of the patient in the transport to ordinary bed, rather than to supply a portable bed for the patient. When the hand grip and operation box are mounted on the chair, the handle can be extended, as shown in Fig. 6(d). At a reclining angle greater than 120°, the patient can be put on the seat after the angle of the chair back has been moved until the end-point of the hand grip rests on the floor without any load generated from the weight of the patient (Fig. 6(e)). When the wheelchair is near the bed, patients can be moved by sliding across the armchair after rotating the armchair if the height of the bed and the armchair are almost the same. This arrangement makes moving the patient to the bed much easier, even in the absence of a lift.

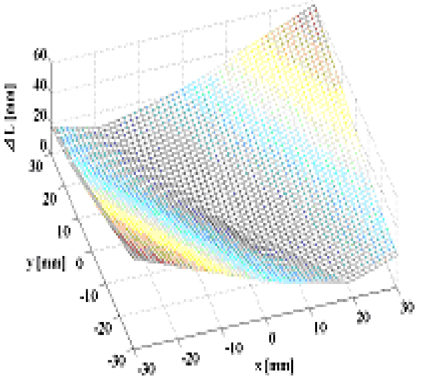
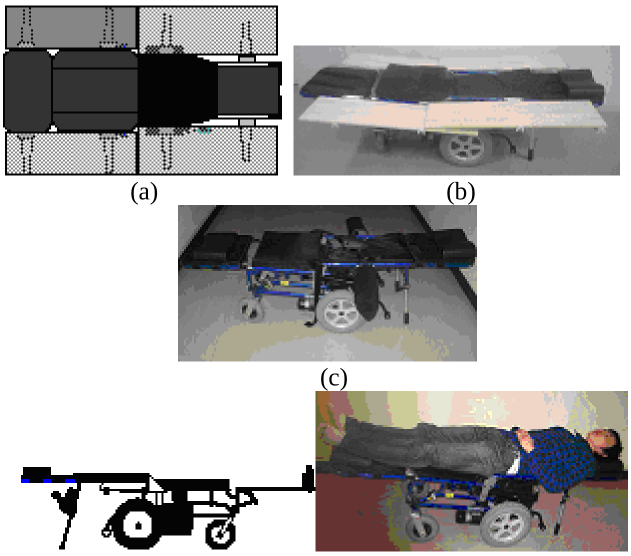


Fig. 5 Stroke Analysis



(a) (b)

(c)

(d) (e)

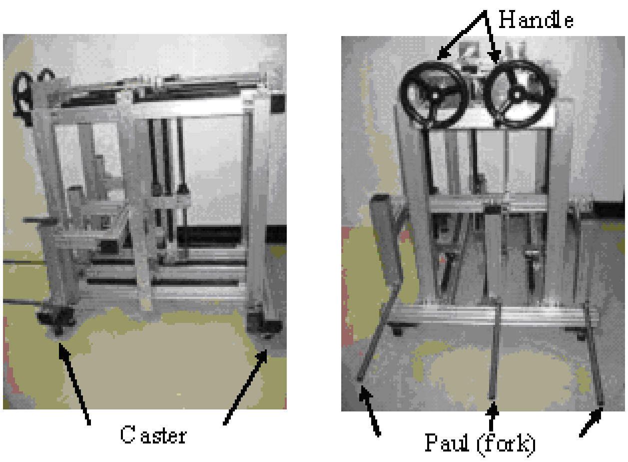
Fig. 6 The Wheelchair is Converted to a Temporary Bed

B. Lift Device

Generally, it is difficult for a caregiver to move a bedridden patient between the wheelchair, the bed and the bathroom. If the caregiver uses neither the lift nor the mechanical actuator, it is possible to have an accident that involves a backache. Also bathing patients who are lying in bed is one of the most difficult tasks for caregivers. Thus, we developed a lift to support transportation between the wheelchair and the bed or bath using a device similar to a forklift. Fig. 7(a) shows caregiver's standing side. Fig. 7(b) shows the lift side and the steering wheel side) Two steering wheels are used to guide the fork manually with two degrees of freedom (up and down and horizontally). The casters that move freely are installed on the bottom of the lift device. This manual lift device has a deceleration gear mechanism composed of spur wheel gears, bevel gears, rack gears, and a ball screw. The deceleration ratio in the horizontal direction is 4:1, and that in the vertical direction is 40:1. An operator can move the fork slowly horizontally and vertically by turning the two steering wheels with a combined force of less than 9.8N (=1.0 kgf) even if there is no power source such as a motor. Using this lift device allows the caregiver to use much less physical strength to move the patient.

C. Bathtub Device

A portable bathtub consisting of polyester fiber waterproof seats which is already produced commercially is shown in Fig. 8 (a) [16]. The bathtub device system consists of a waterproof seat made of polyester fiber and an aluminum frame (Fig. 8 (b)). It is easy to move the bathtub and to clean it because it is on casters and is lightweight. A bus pump is used for the water supply and drain. The exhalation ability for the pump head is about 9 L/min per lifting height of a meter. In some commercial portable bathtubs, the bottom of the bathtub seat is set up on the bed, and in other tubs the floor is supported with the frame. As shown in Fig. 8 (b), our design differs from these because the bathtub is hung on an aluminum frame, with no support material at the bottom other than the room floor. The head of the tub is higher than the foot of the tub by several centimeters, and the foot of the tub is in



(a) (b)

Fig. 7 Lift device

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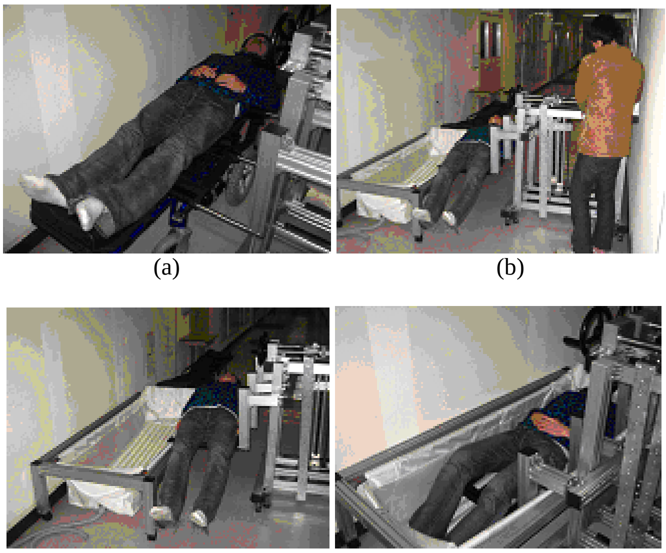
contact with the floor. This tub setup does not require a lot of hot water. The portable bathtub includes an air cushion, which can be refilled if the air escapes. This system allows for ease in bathing, maintains the heat of the bath, and is portable so that it can be taken outside for sunlight sterilization.

D. Transportation of the patient

Here, we describe a method about the transportation of the patient. To maintain the same distance between the forks and the bottom of the bathtub at each place where a fork is attached, the bottom level at the head of the tub is higher than the one at the foot of the tub on the manual lift device. Safety in the event of a collision between a patient or caregiver and the device is ensured by the air cushion.

The caregiver (operator) adjusts the wheelchair to the fully reclining state with the patient lying down (Fig. 9(a)). As shown in Figs. 9(a) and (b), three holes for insert of midair pipes are set in the mattress on the seat of the wheelchair. Three forks (Fig. 7(b)) of the lift device are then inserted into the midair pipes in the wheelchair seat by adjusting the steering wheel after confirming the tolerance quality between the fork and the midair pipes in the wheelchair seat by adjusting the steering wheel after confirming the tolerance quality between the forks and the midair pipes by looking at the connection by the caregiver. Thus, the patient does not have to move during this process.

Fig. 10 shows the transportation method from the wheelchair to the bathtub device using the lift device. First, the caregiver lifts the patient and places him or her on the lift device manually (Fig. 10(a)). The caregiver then pushes manual lift device to the side of a portable bathtub (Fig. 10(b)), and ensures that the bathtub, lift, and patient are all parallel (Fig. 10(c)). The caregiver lowers the patient gradually using the two steering wheels and immerses the patient in hot water in the portable bathtub (Fig. 10(d)). Using this device, it is possible for a single caregiver to give a patient a bath, again reducing the nursing load.



(a) (b) (c) (d)

Fig. 10 The Transportation Method From The Wheelchair to the Bathtub Device Using The Lift Device

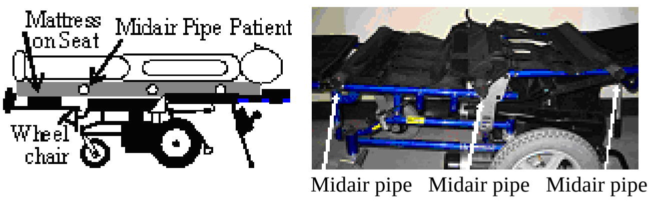
E. Mobile robot with portable toilet

Our goal in this study is to make a robot that would hold and transport the excrement and exhaust it, clean the storage tank by an automatic operation, and move autonomously. Such a robot would greatly reduce an unpleasant part of a caregiver's workload. The mobile robot with storage tank is shown in Fig. 11. The mobile robot which preserves the sewage in a storage tank moves to the nearest restroom and flushes the waste into the ordinary permanent toilet and then washes the exhaust tank mounted on the portable toilet (Fig. 13(e)). By the way the commercial portable toilet as disaster supply etc., has a simple washing device that allows the user to manually flush a small amount of water into the storage tank (Fig. 12). However, this device cannot flush the excrement perfectly because high hydraulic pressure is not generated. Thus, we are trying to develop a toilet system in the mobile robot that can exhaust water into the storage tank and flush it using water in the water storage tank in permanent toilet under electrical control.

We remodeled an electric pump for use with kerosene and set up it in the water supply hole in the upper storage tank of a portable toilet for cleaning, as shown in Fig. 13(a). Hydraulic pressure can be adjusted by squeezing the valve in the electric pump. We set up the experiment with a 2-mm water flow caliber to obtain the necessary water flow velocity. For this experiment, we ignored the viscosity of the water and assumed a steady flow in the pipes. We calculated the flow velocity of the water using a continuous expression assumption, as follows:

$$Q = AV = const. \quad (1)$$

Where Q m^3/s is the volume of flow, A m^2 is a cross-sectional area of the flow tube, and V m/s is the flow velocity. The speed at the caliber of 3 mm is about 1.6 times that at the caliber of 4 mm, and the speed at the caliber of 2 mm is about four times the one that at the caliber of 4 mm. We concluded that the optimal caliber that produces a flow that is not too weak and not too strong, causing water to rebound, was 4



(a) (b)

Fig. 9 The wheelchair with holes to insert three midair pipes

Fig. 11 The mobile robot

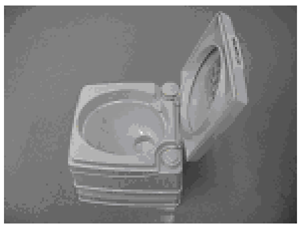


Fig. 12 Portable toilet With storage tank

ISSN: 2277-3754
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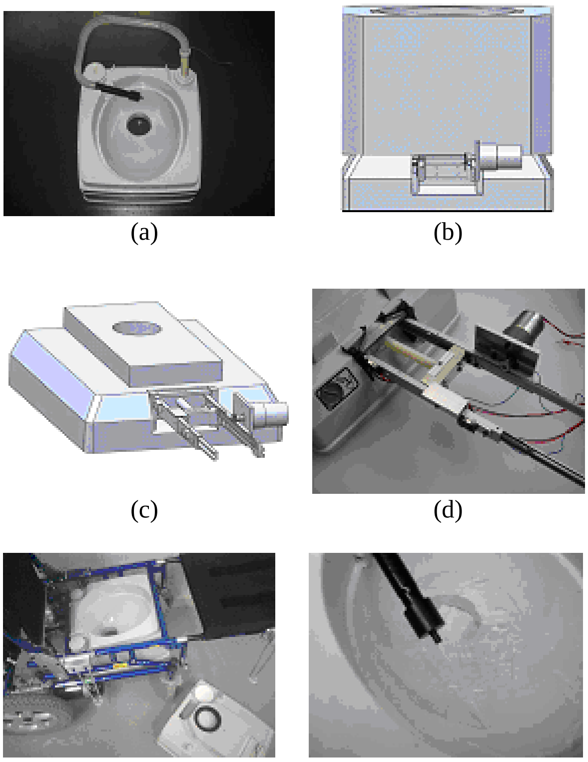
mm. The electric pump will be set up on the arm of the mobile robot in the future work. The arm will be used to flush the excrement to the storage tank below the toilet.

We assume that the robot returns to the wheelchair after the cleaning operation is finished. The mechanism for opening and shutting the valve is installed in the portable toilet to exhaust excrement and is operated by motor control (Fig. 13(b)). The mechanism is shown in Figs. 13(c), (d), respectively. The mobile robot with storage tank, as shown in Fig. 13(e), is able to be stored under the seat of the wheelchair. Fig. 13(f) shows that the mobile robot exhausts water into the storage tank.

III. Specifications of the Mobile Robot with Portable Toilet

A variety of types of equipment toileting assistance have been developed [15]. For instance, Honma and Yamada et al. have developed and tested an overall support robot ''toilet assistance system'' to reduce the load of caregivers [17], [18]. Meanwhile, Kojima et al. have developed an electric wheelchair with a toilet function [19]. The systems developed to date must be cleaned manually, though there are a few studies about simplifying the work within the confines of the conventional technology. To develop a system that requires no caregiver assistance, a permanent device fixed on the floor that includes as water supply and drainage would be necessary. For this reason, we have proposed a mobile robot with a portable toilet that does not need to be cleaned manually and that is easy to use.



(a) (b) (c) (d) (e) (f)

Fig. 13 Portable Toilet Equipped With a Water Valve and Exhaust Control Valve

A. Details of the Expansion and Contraction Mechanism

The mobile robot used for toileting must be installed under the user's wheelchair (Fig. 14). Conversely the robot must exceed and cover the width and height of the ordinary toilet in the restroom (it is discussed later). Batteries for electric wheelchairs are usually installed beneath the seat, as shown in Fig. 14. We moved the batteries to the upper side of the rear wheel axis. As a result, the space under the seat became available for the toileting system. This space is about 400 mm long and 350 mm wide. An ordinary toilet bowl in a private home is 370 mm long and 350 mm wide. Since the bottom of the robot must reach a point higher than the upper part of the permanent toilet in the restroom in residence, the robot has to be able to wrap around the permanent toilet by expanding in depth and width. Therefore, each stroke of 350mm and 120mm in length of expansion and contraction respectively is needed at least.

We have been attempting to design a suitable power source for this mechanism. The stroke of cylinder operation when the fluid is used is long, and the dumping performance must have a healthy and safe design. Such requirements may involve large devices such as compressors and pumps. The control method we installed for the expansion and contraction of the pantograph mechanism electrically uses sensors such as encoders to measure the amount of the rotation, limit switches, and transmission parts such as motors and gears. Then a big stroke is needed for the expansion and contraction in the vertical direction. For example, the pantograph is a parallel link mechanism that has a very high expansion and contraction rate in one direction (shown expanding in the vertical direction in Fig. 15). Thus, we propose a mechanism that combines the simple structure of the pantograph and a slide rail, as shown in Fig. 15. To improve the rigidity and to lighten the body, the pantograph is composed of angled parts with L-shaped structure. The mechanism that moves the pantograph consists of motors with deceleration gears. Each pantograph has a lock mechanism with a high deceleration ratio. Thus, it does not demand any power to supply the motor when the pantograph is being stopped, the power consumption is suppressed.

Fig. 14 Mobile Robot That Fits Under the Wheelchair

ISSN: 2277-3754
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Fig. 15(a) shows the pantograph when collapsed, and Fig. 5(b) shows the pantograph when expanded. One joint at the end point of the pantograph is set as a driven rotation axis (shown as rotation angle θ at point b in Fig. 16), the other one is set as the rotation axis of the pinion gear, which moves on the rack gear (shown as point c in Fig. 16), and the movement of these points makes the pantograph move.

The mechanism does not expand or contract at all horizontally. To resolve this problem, we installed another mechanism besides the pantograph to provide horizontal expansion. The expansion of the width can be satisfied using the slide rail and the rack gear in the horizontal direction, and the mechanism gives two degrees of freedom as the result of that.

B. Design of the Pantograph for the Length Expansion and Contraction

The operation principle of the pantograph mechanism is explained by using Fig. 16. Point b is a fulcrum, and point a moves vertically by moving point c horizontally, and these enable the expansion and contraction of the pantograph in the vertical direction. To obtain expansion and contraction in the vertical direction, we first had to calculate the optimal length of one link of the pantograph. As shown in Fig. 16, the fully extended height, *y* mm, of the pantograph can be expressed as

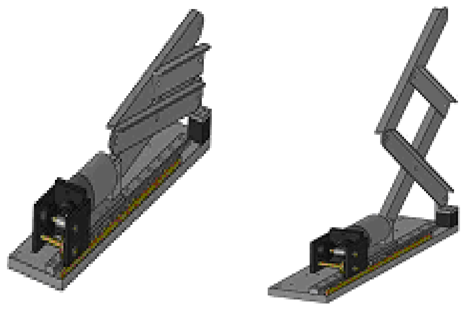
$$y = nL\sin\theta \qquad (2)$$

Using the length, *L* mm, of one side of the pantograph, the angle θ ° between one side of the pantograph and the horizontal plane, and the number of steps, *n*, in the pantograph. From (2), we obtain the result of simulating the height of the pantograph in the case of *L* = 180 mm, 200 mm, 220 mm, and *n*=1, 2, as shown in Fig. 17. The maximum value of the angle θ of the pantograph is set as less than 60° for stability. One side of the length, *L*, of the pantograph depends on the overall size of the robot. For instance, if the robot is too long, when it is folded it will be too wide to fit under the wheelchair. The pantograph mechanism consisting of two steps is selected, the length of one side of one link in the pantograph is selected as *L*=200mm, and it is realized the stroke of 350mm as twice (two steps) is enough if the length of the one side is longer than 200mm.

We have to determine the fold angle of the pantograph for the length expansion and contraction. The mass of a portable toilet is about 3 kg, and the weight of the mobile robot equipped with the portable toilet will be 10 kg when the weight of water for washing and excrement are included. The expansion and contraction mechanism to move along the vertical direction must be designed to carry the weight of $4F_a$ (≅ 98 N) so as to lift the portable toilet, and to exceed the height of the permanent toilet in the residence.

Let the power applied to point a, b, and c be F_a, F_b, and F_c, respectively.

Considering point b as a rotation axis, the relationship between the load F_a N applied below at point a and the power F_c N generated horizontally at point c can be expressed by



(a) (b)

Fig. 15 The Pantographs Of The Mechanism With The Motor

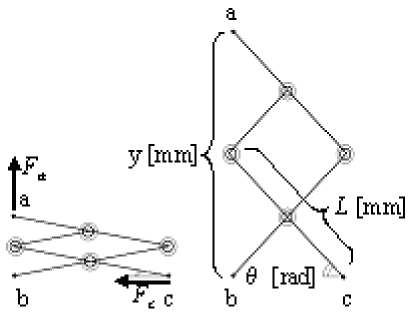


Fig. 16 The Pantograph Mechanisms

$$F_c = \frac{F_a\cos\theta}{\sin\theta} = \frac{F_a}{\tan\theta}. \qquad (3)$$

From (3), it is understood that more power is needed when the angle is small. Since this angle affects the size of the entire robot, the balance between the size of the body and the generation power has to be considered. Substituting (2) into (3), the necessary power

$$F_c = F_a\sqrt{\left(\frac{nL}{y}\right)^2 - 1} \qquad (4)$$

is given. To obtain sufficient lifting power, we had to use four motors under cooperative control by arranging four pantographs. The necessary power and height derived from eqs. (2), (3) and (4) are shown in Table 1. This table shows that 9° is the most suitable angle when the pantograph is folding.

C. Mobile Robot's Movement Mechanism with Omni Wheel

The mobile robot designed using 3D CAD (SolidWorks) is shown in Fig. 18. To prevent the pantograph from coming into contact with the toilet in the restroom, the mobile robot has a U-shaped design to conform to the shape of the toilet bowl.

The mobile robot expands and contracts horizontally and vertically and moves above the permanent toilet, after it enters the rest room under autonomous control. All the movements demand precise control. To allow the mobile robot non-holonomic motion, we installed four omni wheels in a concentric circle at 90° intervals in the movement mechanism of the robot, as shown on our experimental robot in Fig. 19.

As for the drive motors for the omni wheels we used DC motor (model: Japan Servo Co., Ltd, DME34; gear head model: S36G6072B).

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
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D. Prototype Model of the Mobile Robot

The developed experimental model is shown in Fig. 11 or Fig. 14. The total mass of the entire robot is 8.8 kg. As described above, the robot can be installed under the wheelchair even if a portable toilet is installed on the main body of the robot. The robot is about 200 mm high and 320 mm wide in the collapsed state (Fig. 20(a)), 200 mm high and 450 mm wide when expanded horizontally (Fig. 20(b)), and 410 mm high and 450 mm wide when expanded both horizontally and vertically (Fig. 20(c)).

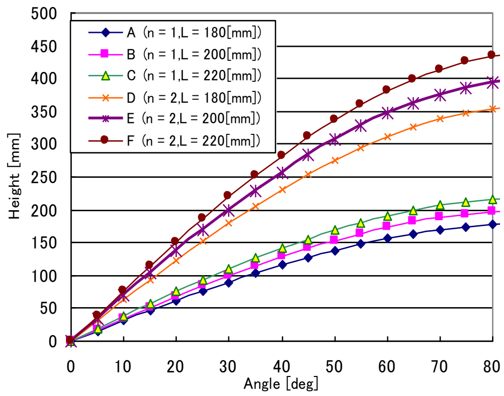


Fig. 17 Stroke Analysis of the Pantograph and the Slide Rail

Table 1 The Relationship between The Angle, Force, and Height of The Pantograph

Angle θ°	Force F_c N	Height y mm
7	203.6	48.7
8	177.9	55.7
9	157.8	62.6
10	141.8	69.5
11	128.6	76.3
12	117.6	83.2

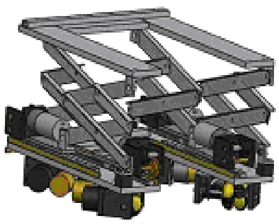


Fig. 18 Mobile robot with Pantograph

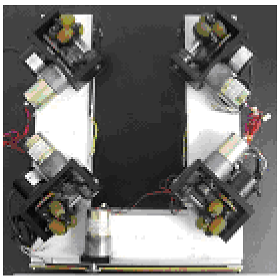


Fig. 19 Omni-wheel drive mechanism

(a) (b) (c)

Fig. 20 Prototype Model of the Mobile Robot

E. Control System Design

The control system for the robot is shown in Fig. 21. The system consists of motors (TAMIYA Co., Ltd., Geared Motor 540K300 for the pantograph, Japan Servo Co., Ltd., DME34B36G6072B for the omni wheels), motor drivers (SANYO Semiconductor Manufacturing Co., Ltd., STK681-210-E), encoders (Line Seiki Co., Ltd.,CB-2500LC), limit switches, batteries, and an H8 microcomputer. Manual expansion and contraction in the vertical and horizontal directions using the H8 microcomputer is possible. Operation is achieved by pushing a button on the board, and the movement can be produced by C language programming semi-autonomously.

The expansion and contraction in the vertical direction requires four motors (Fig. 20(c)), while horizontal expansion requires only one motor (Fig. 20(b)). The system configuration chart to operate the pantograph, the mechanism for horizontal expansion, and the omni wheels was shown in Fig. 19.

The sensor used for the control sequence of the pantograph is a limit switch consisting of a relay with a mechanical point contact. If the motor does not respond to the limitation of motion of the pantograph mechanism, the gear parts and the slide rail driven in overload might cause a breakdown. When the limit switch is activated, by pushing the button-switch on the motherboard, the motor rotates clockwise or counterclockwise contrary to the rotation of the motor.

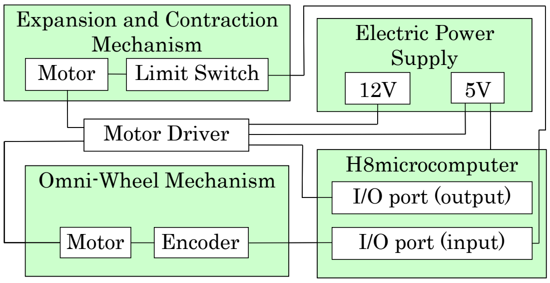


Fig. 21 Control system

F. Experiments

We conducted several experiments with our prototype robot.

1) ***Expansion and Contraction Movement in the Vertical and Horizontal Directions***

We tested the expansion and contraction mechanism of the pantograph and the mechanism of widening in the horizontal direction. The prototype model robot was installed under a wheelchair as shown in Fig. 14, and the robot was extended from the bottom to the top of a toilet in the restroom after getting out from under the wheelchair as shown in Fig. 22. The test confirmed that the specifications for the expansion and contraction mechanism were satisfactory. The automatic control operation for expanding horizontally using the microcomputer is shown in Fig. 23(a). The automatic control operation for expanding vertically is shown in Fig. 23(b). It is understood that it takes about two seconds to expand in the vertical and horizontal directions.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 5, November 2012

2) ***Confirmation of Payload of the Pantograph for Length Expansion and Contraction***

It was confirmed that it was possible to lift a 2 kg weight using the pantograph, with the driving motor for the lift attached to a 12V power supply.

3) ***Confirmation of the Move Mechanism in the Mobile Robot***

Fig. 24 shows the various movement patterns in the mobile robot; (a) spin turn, (b) pivot turn, (c) curve turn (all steering), and (d) curve turn (front steering). Here, to test the mobile robot with omni wheels, we had it rotate (spin turn) move forward and back, and perform a slide-aside movement. Fig. 25 shows the result of the spin turn test under automatic control operation. The robot's ability to perform these movements was confirmed. In a future test we will confirm the turn operation of curve turn ((c), (d)) as part of several floor map situations in public buildings or a house. We also plan to install a camera and an encoder, and to execute an autonomous movement experiment while recognizing obstacles.

IV. FUTURE WORK

Currently, the autonomous control system for the mobile robot with a portable toilet is under development [20]-[24]. In the future, the development of the robot that can clean its body while supplying water from the water tank in the rest room by two manipulators mounted on the robot will be tried. The robot has to move safely on the visual basis of the edge between the floor and wall without any lines needing to be installed in the houses. The robot will be able to move based on the observations while switching between its several cameras automatically. Our goal is for families to be able to care for patients currently receiving full-time nursing care by using the proposed system. In various nursing situations, we try to test of the service robot at a variety of actual job.

Fig. 22 Mobile Robot Surrounding a Toilet

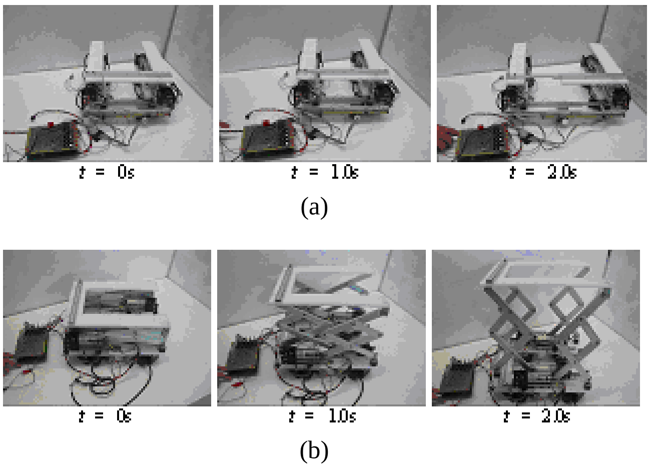


Fig. 23 Experiments of Robot's Size Changes and Spin Turn

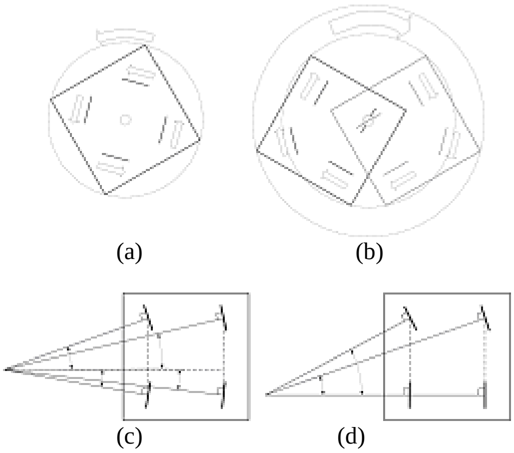


Fig. 24 Geometry in Steering

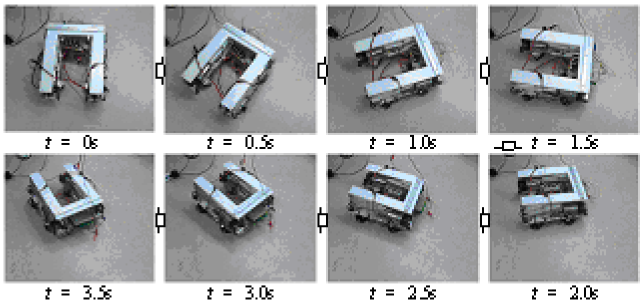
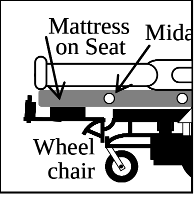


Fig. 25 Experiments Of Robot's Size Changes and Spin Turn

V. CONCLUSION

We have described a nursing-care system for support equipment to aid in locomotion, sleeping, bathing, and toileting, designed to improve the quality of life (QOL) of handicapped people. The proposed system included a way to convert an electric wheelchair into a portable bathtub device. A lift device and a mobile robot with a portable toilet were also developed. Using these items, caregivers can more easily carry/bathe patients alone. Also, we proposed a nursing-care function that can decrease the load of caregivers by providing automatic emptying and cleaning of a mobile toilet by a mobile robot. We tested the mobile robot using the microcomputer control system, and confirmed that it works as designed. The robot can be realized the various movement patterns such as spin turn, pivot turn, curve turn and curve turn.



ACKNOWLEDGMENT

This work was supported by KAKENHI (No. 20500482, 2008-2011).

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