

Development of an Emergency-shutdown System for the Commercially-supplied Joystick-type Electric-wheelchair

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Abstract

An emergency-shutdown system has been developed to be mounted on the existing joystick-type electric wheelchair so that the wheelchair is halted when disabled or elderly riders make operational errors caused by strain. Operational errors are often made when pedestrians appear suddenly in front of a rider and this causes the rider to grab the joystick tight, or to tilt the joystick so hard that the stick is fully throttled. A simple system, which detects errors with a pressure-sensitive switch and operates a self-holding current-shutoff system thereafter, was developed as a system applicable to conventional, commercially-supplied electric-wheelchairs. The development results are described.

Keywords

emergency-shutdown system, joystick, electric wheelchair, operational errors, pressure-sensitive switch

1. INTRODUCTION

1.1 Background

Electric wheelchairs are an essential mobile tool for severely disabled people. Electric wheelchairs are usually divided into two types: the scooter-type and joystick-type. The joystick-type electric-wheelchair is easy to operate, as the wheelchair will move in the same direction as the rider moves the joystick. However, some wheelchair riders are not familiar with the operation of the joystick, or some riders make some sort of unsuitable reaction in cases such as when someone suddenly jumps in front of the rider, or again when the rider is surprised by a loud noise which makes them very nervous. In such cases, actions including pressing the joystick unnecessarily hard may be taken by the rider, the control of the electric wheelchair may become impossible, and this may lead to an accident.

Though wheelchairs are essential for severely disabled people as a means of movement, no measures have yet been taken towards recognition of risk and safety for users. Annually more than 200 cases of electric-wheelchair-related traffic-accidents occur in Japan, and annual fatal accidents account for more than 10 cases [National Police Agency, 2009]. The figures are based only on the number of accidents reported to the police, and thus, potentially, more accidents are occurring.

Currently, research and development are conducted for the safety of wheelchair users by using various

kinds of sensors and the latest technologies, such as: “Intelligent Electric-Wheelchairs” [Sato and Sakagami, 2006], aiming at providing the rider with safety by allocating a plurality of stereo cameras and analyzing omnidirectional information; and the “Development of a Collision Warning System for Electric Wheelchairs” [Murota et al., 2006], aiming at collision prevention between electric wheelchairs and cars through the help of “Pedestrians ITS (Intelligent Transport Systems)”. These technologies will be, possibly, provided in new electric-wheelchairs in the future. But they are not effective steps for preventing the running away of electric-wheelchairs caused by operational errors by the rider.

The efforts made in development, such as the development of a built-in safety-system for new electric-wheelchairs, include R&D for: detecting the user’s reaction in an emergency situation by using EMG (Electromyography), of which the targets are people with a high-level of spinal cord injury [Han et al., 2003]; operating the electric-wheelchair by detecting the user’s head-movement with the help of artificial intelligence [Joseph and Nguyen, 1998]; ensuring the safety of the rider by a combination of ultrasonic sensors, which detect obstacles around the rider without any contact, and a force-resister rubber-switch sensor, which makes detection by contact (Fujimoto, 2006); and operating electric-wheelchairs not by using a joystick but by allocating small wheels on the right and left sides of the armrests of the electric-wheelchair and operating the electric-wheelchair with the same movements as a manual wheelchair (Wada et al., 2000), (these latter two cases are under patent inside Japan). Meanwhile, a total of 115,080 joystick-type electric-

wheelchairs were sold between 1985 and 2006 in Japan [Association of Electric Wheelchair Security Spread, 2009]. Given the number of sales of electric-wheelchairs and their durability, presumably 70,000 to 80,000 of the wheelchairs are still being used today, and this type of electric wheelchair will be ridden on the streets for at least 10 more years. Though a system which ensures safety in emergency situations needs to be added to existing electric-wheelchairs, such a system has not been commercially supplied yet. That is, a safety measure for electric wheelchairs needs to be supplied as a system which can be added to the electric wheelchairs which have been sold commercially so far, as well as a system which prevents a running away of the wheelchair caused by operational error.

1.2 Purpose

The purpose of this study is develop a system by which an electric wheelchair will be shut down in an emergency, to ensure the safety of users of existing joystick-type electric-wheelchairs in cases when the users are not familiar with the operation of the wheelchair, or when the users face a loss of control because of strain and neural reflex in emergency situations. Moreover, the system should be mounted on conventional products.

- (1) A system which can easily be mounted on the existing electric-wheelchair.
- (2) A system which involves only a small economic burden when mounted on the existing electric-wheelchair, as well as being affordable.
- (3) A system which is operated basically in the same way as it was by users earlier and which the users can operate without feeling a sense of discomfort.
- (4) A system which can prevent the running away of wheelchairs caused by the user's disability, especially by excessive reflex or strain.

2. PRINCIPLES OF THE EMERGENCY-SHUT-DOWN SYSTEM

2.1 Operating principles

The operating principles of the system developed will be described here. Some users of electric wheelchairs become severely strained or show some unsuitable neuron reflex when they encounter a situation where a person or people suddenly jump in front of them. In such a situation, this system enables the wheelchair to undergo an emergency shutdown in two cases: (1) when the joystick, which is an input device for operating the electric wheelchair, is grabbed very hard by the user; (2) when the operation lever of the joystick is tilted hard and the stick is fully throttled by the user. The wheelchair can be restored to an operational condition by pressing a push-button after being shut down. This system can be easily mounted on joystick electric-wheelchairs which have been already supplied commercially.

A description is made here of the emergency shutdown which operates when the joystick is grabbed hard as part of the system. When the rider grabs the operation lever of the joystick hard because of strain, this behavior is detected by the pressure-sensitive sensor embedded in the lever, and the driving power of the wheelchair will be shut down. Furthermore, when the rider abruptly tilts the operation lever of the joystick very hard and the joystick becomes fully throttled, the excessive tilt of the lever is detected and the driving power of the wheelchair is shut down.

2.2 System configuration

A description will be made here of a system which can realize the method above. A configuration diagram of the system is shown in Figure 1. The electric wheelchair comprises: frame, wheels, seat, sections of a joystick and operation control, a motor, and a power source (battery). The emergency-shutdown system de-

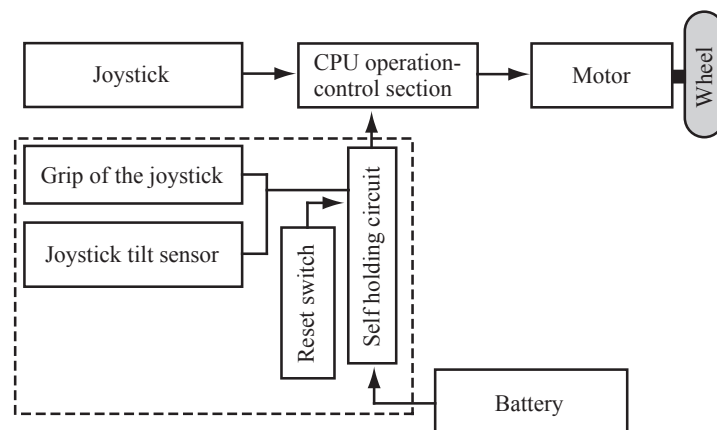


Fig. 1 Configuration diagram of an emergency-shutdown system for adding to an electric-wheelchair (The battery power is shut down in an emergency and is turned on again by the reset switch.)

scribed in this paper comprises: a joystick which has a pressure-sensitive sensor built into the grip, a pressure sensor at the joystick base-area for preventing full-throttle, a reset switch, and a section of self holding circuit.

A flowchart of the emergency-shutdown system is shown in Figure 2. The electric wheelchair was originally designed for riders to avoid emergency situations they encounter by moving the joystick in the direction of safety or by taking their hand off the joystick to stop the electric wheelchair. However, for example, if the user of an electric chair feels very tense, or if the hand or arm becomes strained when somebody suddenly jumps in front of them, the user easily takes up such actions as grabbing the joystick hard or inclining the joystick in the direction of movement. These actions do not help the rider from avoiding emergency situations and can create extremely dangerous situations which may lead to an accident. In such an emergency, these sorts of exceptional actions on the part of the operator of the wheelchair are detected by this system's sensors. Accordingly, the emergency-shutdown system is activated, the stop signal is sent, the power supply from the battery is shutdown, and the electric wheelchair will be stopped. Once it is stopped, the reset switch of this system can be operated after verification of safety is made. Thereby the emergency-shutdown system is deactivated, the power supply is restored, and then normal operation of the wheelchair

becomes possible.

3. DEVELOPMENT OF PARTS FOR THE EMERGENCY-SHUTDOWN SYSTEM

3.1 Outline

3.1.1 Joystick base-area, the grip, and reset switch

The joystick base-area and the joystick grip of the system are mounted after removing the original joystick base-area from the existing electric wheelchair. (Figure 3). Sensor I has a function which is activated when the joystick is inclined in the direction of movement of the wheelchair more than an inclination made in a normal operation. "a" in Figure 3 is the joystick base-area, where Sensor I is built in.

Sensor II has a function which is activated when the joystick is grabbed harder than in a normal operational situation. "b" in Figure 3 is the joystick grip, where Sensor II is built in. Exceptions to normal are detected by either Sensor I or Sensor II, and then the emergency-shutdown system is activated. The reset switch is needed for restoring the system so that normal operation of the electric wheelchair can be resumed after the wheelchair is stopped. The switch is marked as "c" in Figure 3. A push button is used as the switch.

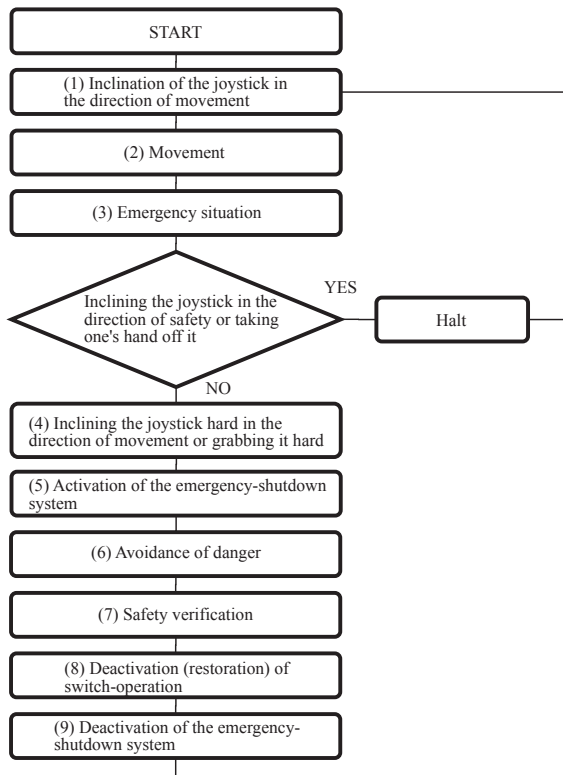


Fig. 2 Flowchart for the emergency-shutdown system

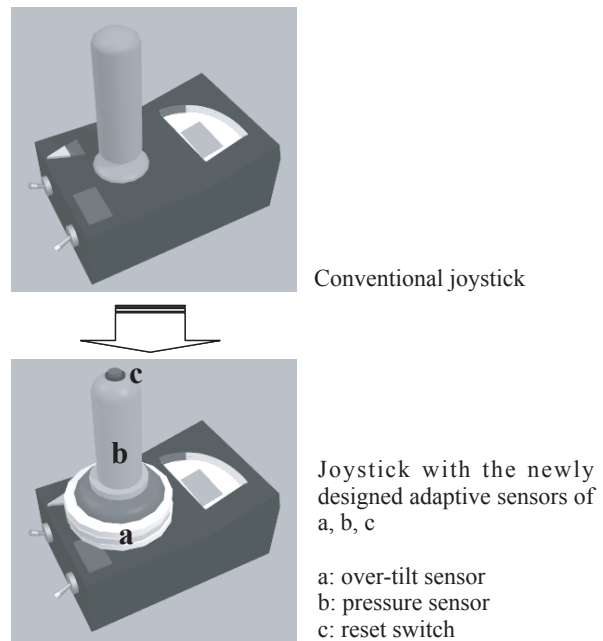


Fig. 3 The joystick grip before and after the base-area is replaced

3.1.2 Power-shutdown control-section of the emergency-shutdown system (control section)

The power-shutdown control-section of the emergency-shutdown system is connected between the operation-control section and the battery area of the electric wheelchair. When a signal is output from Sensor I or Sensor II, the control section of the emergency-

shutdown system, which is a self-holding circuit, is activated, the power source is shut down, and the electric wheelchair is halted. The interlock of the power-source shutdown section is discharged by operating the reset switch, the power is turned on, and normal operation of the electric wheelchair can be resumed.

3.1.3 Pressure-sensitive rubber-sensor (code switch)

A description will be made of the pressure-sensitive sensor for Sensor I and Sensor II, which are built into the joystick base-area and the joystick grip (Figure 4).

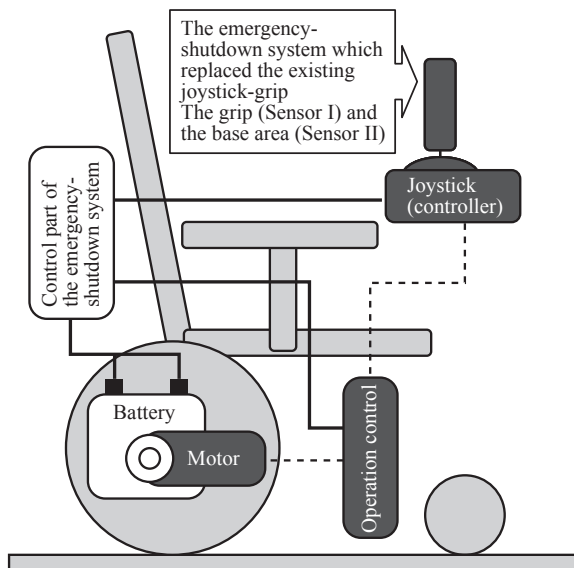


Fig. 4 Schematic diagram of the emergency-shutdown system

A pressure-sensitive rubber-sensor is used in this study, whereby the circuit conducts when pressure is applied. The pressure-sensitive rubber-sensor is structured by sandwiching the pressure-conductive rubber (PCR) between flat braided wire and integrating them with silicon rubber. (Figure 5) [Bridgestone, 2003]. The resistance of the pressure-conductive rubber (PCR) changes from $M\Omega$ to $0\ \Omega$ when it is pressed (Figure 6). The pressure-sensitive rubber-sensor is

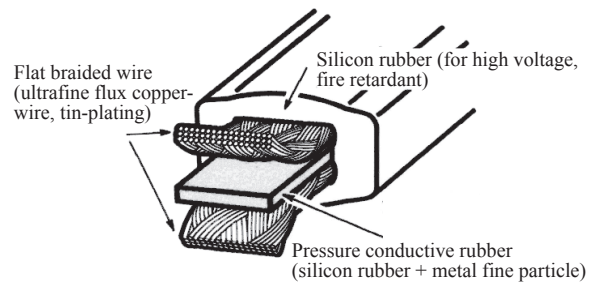


Fig. 5 Inner-structure of pressure-sensitive rubber-sensor, which is a combination of pressure conductive rubber and flat braided wire

also: (1) flexible; (2) highly durable since it has no mechanical area; and (3) selectable by the users depending on the situation, since the operating pressure of the pressure-sensitive rubber sensor varies. Thus, a pressure-sensitive rubber-sensor was chosen in this study as the sensor for the emergency-shutdown system.

3.2 Self holding circuit

A self holding circuit diagram of the emergency-shutdown system is shown in Figure 7. Manufacturing is possible at a low price, because (apart from the sensor areas and the reset switch) the parts required are only for the relay (2 terminals), the battery (2 terminals), cables, and a box.

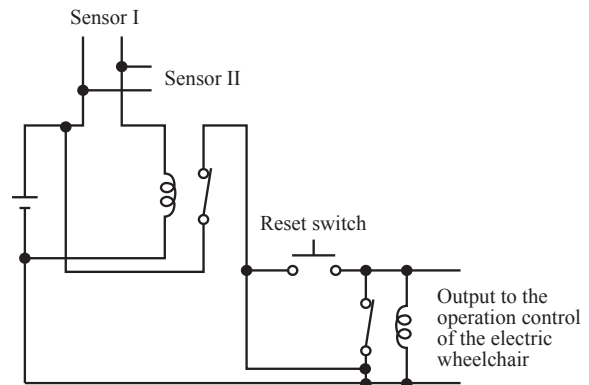


Fig. 7 Self holding circuit diagram

Operating principle of the pressure conductive rubber (PCR)

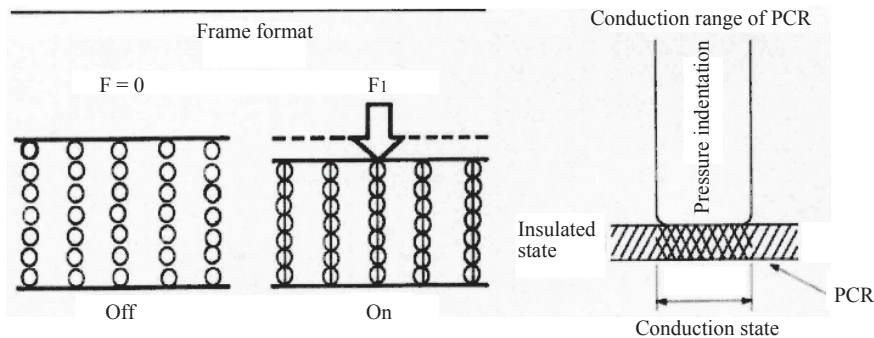


Fig. 6 Operating principle of the pressure conductive rubber (PCR)

4. THE SYSTEM FOR PROTOTYPE

4.1 The electric wheelchair used for the prototype

The electric wheelchair EMC-230 made by Imasen (Imasen Engineering Corporation) was used as the prototype. The electric wheelchair EMC-230 was selected because it is used as widely as the Motor Chair made by Suzuki Motor Corporation inside Japan.

4.2 The joystick base-area

The joystick base-area is shown in Figure 8 as (A) and (B). At the area (A), between two 5mm-thick plastic circular-discs, two 5mm-thick/5mm-wide urethane-bars are placed parallel to each other along the circular disk, and the pressure-sensitive rubber sensor (Sensor I) is put in therebetween. The circular discs used at (A) have a hole. The joystick grip (C) inclines from a perpendicular position—that is, the stop position—to optional angles within an omnidirectional range approx. 15-degrees when the electric wheelchair is moving. Through the movement of the joystick, the operation of the electric wheelchair becomes possible in the directions, and at the speed, intended by the users. Thus, the size of the hole in (A) needs to be big enough not to impede the movement of the joystick. Two unfixed circuit discs in (B) are used to cover the hole. In this structure, the normal movement of the joystick (C) is not impeded, and when the joystick is inclined hard in an emergency, the movement at the lower end of (C)

is passed on to (A) and the pressure-sensitive rubber-sensor is pressed.

4.3 The joystick grip

The joystick grip is shown as (C) in Figure 8. The upper-part (100 mm) of the round bar is made as a square; the pressure-sensitive rubber sensor (Sensor II) is arranged in series on each side of the square and the urethane bar is put there around.

In this structure, the pressure-sensitive rubber-sensor is pressed and conducts when the user of the electric wheelchair grabs the joystick strongly in an emergency.

4.4 Disengage (restoration) switch

The reset switch is shown as (D) in Figure 8. The reset switch is set in the upper part of the joystick grip (C), and restores the electric wheelchair from its stop status to enable the user to resume usual operation after the emergency shutdown system has been activated. An automatic restoration of the electric wheelchair after the emergency-shutdown system is activated was also considered without a reset switch. But restoring the wheelchair without resolving the cause which activated the emergency-shutdown system may trigger a dangerous situation; thus, in this system, the restoration of operation is to be made by the user after the user has ensured his/her safety and then operates the reset switch.

4.5 Study of movements

The manufactured prototype was mounted on an electric wheelchair and its movements were studied (Figures 9 and 10). The wheelchair was ridden by an unimpaired subject. It was operated normally and safety verified with the prototype mounted. Then, the joystick was grabbed hard and was inclined hard voluntarily in the direction of movement. Each action was repeated five times. In all conditions, the electric

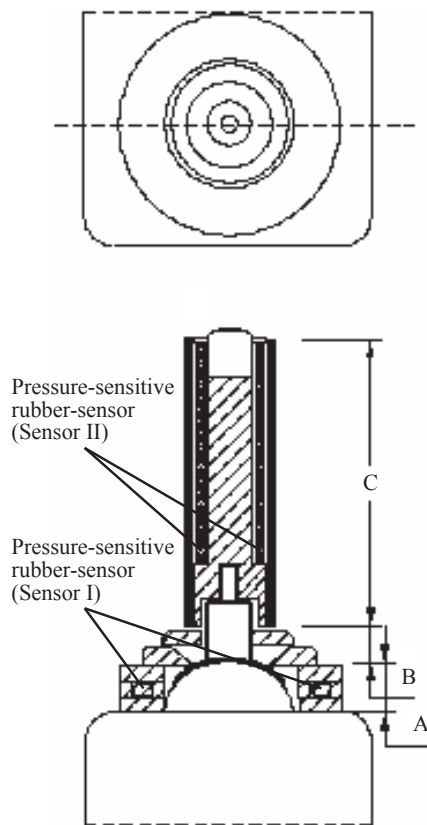


Fig. 8 Cross-sectional diagram of the joystick



Fig. 9 The newly designed grip and base-area mounted on the joystick



Fig. 10 Trial examination using an electric wheelchair with the prototype mounted

wheelchair stopped running immediately after each action was conducted. Restoration was also verified by pressing the reset switch placed on the upper part of the joystick in each case.

5. CONCLUSION

The emergency-shutdown system was developed for the purpose for ensuring safety by stopping the electric wheelchair both when the existing joystick-type electric wheelchair is ridden by a user who is not familiar with operating it, and when, though the user is familiar with its operation, the wheelchair goes out of control due to the user's severe strain or the user's inappropriate reflex in an emergency. The study is summarized as follows:

- (1) The emergency-shutdown system was developed by using a pressure-sensitive rubber sensor, and the system can be added to existing electric wheelchairs easily at a low price and can be operated in the same way as for existing electric wheelchairs.
- (2) The possibility of using the pressure-sensitive rubber-sensor was verified for the system; the selection of a cord switch which has a variety of operational pressures is possible depending the various conditions of the user, and other individual support has become possible.
- (3) Though Imasen's electric wheelchair was used for the prototype of this study, the emergency-shutdown system is not limited to Imasen's structure. Because many of the electric wheelchairs used widely inside Japan share the same structure for the area where the emergency-shutdown system is added, the system can be mounted on wheelchairs produced by other companies if the size of the joystick and the method used for fixing the joystick to the wheelchair are arranged properly. Thus, the system has versatility.

The system developed in this study has novelty in that the system can be used by loading it onto existing

electric wheelchairs as an additional system, and this system should have considerable utility.

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