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Augmenting Intuitiveness with Wheelchair Interface Using Nintendo Wiimote

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ABSTRACT

The natural interaction aspects of the user interface are more significant in the devices of impaired users than the devices of healthy users. This work investigates three controls as the wheelchair controllers according to the design and physicality principles; conventional joystick, isometric joystick, and quad-directional button. Our aim is to provide further ease of use to the impaired whilst strengthening link between embedded software engineering and human-computer interaction. We conclude that an improved multi-function interface design by using Nintendo's Wiimote quad-directional button is more intuitive, flexible and natural to use.

KEYWORDS

Physicality; embedded software; wheelchair controller; user interface design; natural interaction.

1 INTRODUCTION

Impaired people are more sensitive to the user interfaces (UIs) of their assistive tools and devices. This limitation must be considered at the design time of these devices. Among assistive tools for impaired people, the mobility assistive tools are heavily used. In US alone, approximately 4 million people use assistive wheeled mobility devices, with about 17% using electric power wheelchairs [27]. A wheelchair can have different types of UIs based on various factors including the power source, that is, hand-driven; hand-power-driven; or intelligently/sensor-power-driven. The hand-power-driven wheelchairs use various controllers including; joystick, trackball, head array, touch pads and various types of buttons and switches.

The natural interaction is the combination of human innate abilities and the physical visceral qualities in the artefacts [1]. The visceral quality is that physical aspect of device which recruits our natural human abilities [2]. Physicality as defined by Donald A. Norman [3] is "the return to mechanical controls, coupled with intelligent, embedded processors and communication". The importance of physicality is evident from many examples. The notational and social aspects of physical artefacts cannot be ignored in agile software development [4]. Pilots of commercial airlines use papers for many purposes including managing attention [5]. Physical representations are difficult to ignore than digital reminders [6]. McKinnon [7] states, "(Some software) helps you effortlessly create new ideas, break them down, arrange them, colour code them but most importantly - print them out to use them as technology in their own right".

There are two popular types of joystick; conventional joystick (CJ) and isometric joystick (IJ). The difference between the two is that when the user exerts force, CJ moves itself significantly whilst IJ does not move itself. IJ as a pointing device has been used in various laptops, computer mice, and desktop keyboards. It occupies little space providing only single finger operation. Different brands have different names for IJ including TrackPoint by IBM/Lenovo, PointStick by HP, NX Point by NEC, Pointing Stick by Sony and Unicomp, StickPoint or QuickPoint by Fujitsu, Track Stick by Dell, AccuPoint by Toshiba, and FineTrack by Acer.

Nintendo's Wii is presently the largest selling video game around the world [18], [19]. The controller of the game is called Wii remote or Wiimote. The reason behind using Nintendo's Wiimote for wheelchair interface is its better interaction capabilities. It has more flexibility and scalability than conventional components used in wheelchair interface. Wiimote has a quad-directional button (QDB) also called control pad, eight other buttons, 3D motion sensing, and pointing functions for input purpose and a speaker, rumble pack, and four LEDs for sound, tactile, and visual feedback, respectively. In this work we investigate and compare the design principles of CJ, IJ, and QDB.

This paper is organized as follows. The next section describes motivation and related work followed by introduction of physicality principles and then introduction of controllers. Subsequently we compare the physical and logical mappings of three controllers. Before discussions and conclusion we analyse the three controllers according to design and physicality principles.

2 MOTIVATION AND RELATED WORK

Among the vast application areas of embedded software systems, we look into the interface design of assistance devices for physically impaired people. Wheeled mobility devices are heavily used tools by the impaired people around the world. Although a lot of work has been done in the past on the solutions for the impaired people but the specific area of interface design of controllers has not yet received appropriate attention. In order to have a deep understanding of the requirements-availabilities relationship, we investigate the problems and solutions of firstly blind impaired people, and secondly the mobility impaired people. In this way we can be better able to design a natural interface for wheelchair users keeping in mind that blind users also need to interact with the wheelchair.

For our study, we also visited hospitals, impaired people's care centers, interviewed impaired children and their caregiver staff, and observed the ways in which impaired people interact with their wheelchairs to gain first-hand knowledge of their needs. The impairment that leads to the use of wheelchair may be caused by many diseases or injuries of spinal, muscular, brain, legs or feet.

Recently some efforts have been made to bridge the gap between software engineering and human-computer interaction and to provide ease to the embedded software developers. Kim et al. [25] have proposed a user behavioral analysis framework for the ubiquitous embedded systems. Bujnowski et al. [8] empirically analysed the use of tactile system to guide the visually impaired people during walk. Although they used tactile vibrators on subject's one arm only, still their results showed that tactile feedback is more comprehensible to the blind. This work can be enhanced easily by increasing the directions from three to five or even more. At each arm, small duration vibration would mean turn left 45^o, and long vibration would mean turn left 90^o, while vibration on each arm simultaneously would mean to move forward. The study by Hara et al. [9] has also proved that the tactile feedback is better than audio, especially in outdoor's possibly noisy environment. The results of Shah et al. [10] have also confirmed the former studies. Based on these studies among many others it can be concluded that the tactile sense of visually impaired people is more sensitive and better than audio feedback.

Ivanchenko et al. [11] have proposed a computer vision based solution. A camera and high speed computing device for graphical processing of images made the system costly besides other flaws. This approach targets the visually impaired users who may have additional mobility difficulties. This system engages an arm of user all the time which is laborious especially for an impaired person. It is difficult for fixed camera to monitor the free moving cane. Lastly, the computer vision program needs improvement by categorizing the friends and foes among obstacles. Kuno et al. [12] have come up with even costlier wheelchair interface solution having multiple cameras, high speed computing machines for image processing, and automated control of wheelchair. The solution has overwhelmed the user with many controlling points and strict limitations on head movement for the user. Any slight movement of head for communication with some person or for enjoying the environment will result in the unintentional change of direction of wheelchair that may end up in an accident. The system is designed in a way that the back camera tracks and follows the movement of caregiver. However, the back camera can interpret any pedestrian as caregiver because authors have not designed anything to identify the caregiver. As the caregiver control has priority over user control, in case of wrong selection of caregiver the user is helpless especially at a busy place like market. This system indicates a lot of enhancements to be made on the interface of the system besides functionality. Abascal et al. [13] have proposed a mobile interface for the patients of quadriplegia (who are unable to use their arms and legs) that is low cost, automatic, and requires less effort by the user. It also takes into account the activeness of user for rehabilitation purposes. The user can select the available paths after scanning a matrix of icons, with a pushbutton or a joystick. To select a destination the user is provided with a hierarchical map model due to compact menu-based display. The presented entries for the destination to the user are optimized by two ways. First, only the reachable destinations from the current point are displayed to reduce the time and effort of user in selection. Second, the displayed options are ordered based on the frequency of selection by the user. However, the user interface needs enhancement. In all the discussed scenarios we have found spaces for improvement in the user interface.

Duran et al. [32] proposes the use of wiimote instead of joystick for holonomic wheelchair control by exploiting Wiimote's 3D sensor movement facility using gestures. Authors want to reduce the interaction with the wheelchair controller to reduce mental workload and introduce relaxed interaction. The aim is to remove the limitation of using buttons or knobs to facilitate the riders with specific kind of cognitive and physical disabilities. Hand manipulations holding wiimote are translated into the displacements of wheelchair. The system consists of wiimote, laptop or PC, Bluetooth dongle and holonomic robotic wheelchair. The three wiimote movements are translated into three wheelchair movements; pitch, yaw and roll to move forward/stop, turn right/left, and steering right/left, respectively. In comparison tests it is proved that wiimote control requires less movements and hence more intuitive than joystick controller.

3 INTRODUCING THE DESIGN AND PHYSICALITY PRINCIPLES

The physicality principles have not yet applied on the wheelchair interface to introduce natural interaction. Embedded software developers emphasized on functionality by providing multiple complex interfaces simultaneously for a single chair whilst ignoring the usability and fluid interaction aspects, completely. Users like a naturally used device no matter how simple it is but dislike a very sophisticated device having poor interaction. We briefly discuss here the design and physicality principles for natural interaction. We will evaluate the existing controller and compare with other controllers according to these principles in detail in section 7.

If a control expresses its underlying logical state by its physical state then this control holds the property of exposed state. For example, simple on-off light switches. If the physical appearance does not express the logical state then it is called hidden state. For example, twist control of a speaker. The directness of effect property is directly proportional to the action performed. A small push results in small movement and a large push results in large movement. Locality of effect means the result of an action should be there and then. A control having bounce back effect maintains a state until operated then either stays or returns back to its initial physical state. For example, push button. Cultural influence indicates the frequency of usage in a society. Affordance is the number of action options perceived by the user. Compliant interaction shows the symmetrical aspect of interaction between user and system. Physical and mental requirements are the amount of physical and cognitive efforts, respectively that are needed to perform an operation while interacting with a control.

4 CONTROLLERS

The controllers of the wheelchair may include various kinds of joysticks, trackball, head array, touch pads and different type of buttons and switches. We have selected IJ and QDB to be compared with the existing CJ controller. The existing system [15] is a non-commercial wheelchair developed by embedded system students of a university. This wheelchair has triple-user interface; hand-power-controller (with CJ); automatic-power with sensors; and manually by using rim (Fig. 1).

Fig. 1. Subject wheelchair.

We introduce three controllers CJ, IJ, and QDB in subsequent subsections.

4.1 Conventional Joystick

CJ has been widely used as a wheelchair controller. When user applies force on CJ, it moves itself whilst forwarding the user input to the wheelchair as output. In this way, the joystick movement guides user during the interaction. In existing wheelchair [15] CJ is used (Fig. 2).

Fig. 2. Conventional joystick (CJ) mounted on controller box of existing system.

The joystick has a metal stick with hard plastic head. It is 3cm in vertical length or height mounted on a controller box. The controller box holding the joystick is occupying further 3cm height resulting in a total height of 6cm from the wheelchair arm. This occupies a lot of space and reduces the seating and operational space for the user. The clothes of user may stick to the joystick during seating or leaving the chair. This may result in the damage of device. There is no labeling for guidance to indicate any direction. Among 360^o, user cannot predict the operational range of joystick. This is an example of lack of affordance. The joystick is a bounce back control [16] as it returns to its initial position after the release of pressure. However, this CJ has a hidden state property and therefore it needs to have some labeling for the directions [17].

In addition, this joystick needs to be grabbed or grasped with fingers to operate. Whilst we are focusing on the impaired users, among them patients having no fingers may also use this wheelchair, for example leprosy patients. Therefore, this control is approximately unusable or very difficult for the people having no fingers. Another problem of the existing CJ is that it is twistable and rotatable in clockwise and anticlockwise direction, having no logical functionality. The physical-logical mapping is absent here that will only confuse the user. One more limitation of this CJ interface is the introduction of four screws that are holding joystick module inside the controller box. The screws on the box hinder the use of joystick because these are well above the surface. The edges of the screws may injure the user in any unintentional or careless handling of device.

4.2 Isometric Joystick

IJ is a type of joystick that does not move itself but translates the input of user into electronic form and forwards to the underlying system. Therefore, it does not provide any kinesthetic feedback to the user. User only gets a non-visual feedback in the form of feeling back-pressure in exerting force on the joystick. In contrast to CJ, IJ requires less space. It has been frequently used in hand-held devices or mobiles including powered mobility [27], mobile phone [28], and electric power wheelchair [29]. In [29] authors have conducted a comparison study between virtual and real electric powered wheelchair maneuvering using a position sensing joystick and an isometric joystick. In [30] authors have conducted comparison study of three controls for browsing World Wide Web including scrolling and pointing actions. These three controls include mouse with IJ, wheel mouse, and two handed keyboard and mouse. In [31] gestures of isometric joystick are used to enter text in mobile phone (Fig. 3c). IJ is also used with mouse (Fig. 3a) and keyboard (Fig. 3b).

(a) IJ in Keyboard [30]

(b) IJ in Mouse [30]

(c) SC1100 Smartphone augmented by IBM's TrackPoint IJ on front and back [31]

Fig. 3. Some uses of IJ.

Although isometric controls are found less intuitive in start but after gaining experience these may be less fatiguing and result in smoother movements [33]. Vast applicability of IJs in various devices makes it a good candidate to be used in our study. There are few other studies that have used IJ for imddpaired users in mobility assistive devices and compared with conventional joysticks especially for the patients suffering from cerebral palsy, and duchenne muscular dystrophy [34], [35], [36], [37].

However, none of these and other studies have addressed the physicality principles. Motion sensing joysticks have also been used with wheelchairs. Due to desirable features of IJ, currently research is in progress in the area of embedded system to improve IJ. It has been exercised by augmenting IJ with intelligence and control by using the programmed microprocessor [27]. Many shapes or caps of IJs are used for example soft rim (Fig. 4a), soft dome (Fig. 4b), and classic dome (Fig. 4c).

(a) Soft rim

(b) Soft dome

(c) Classic dome

Fig. 4. Example caps of IJ.

Instead of using different or new controllers for different devices; resulting in learning effort, handling burden, space occupation, cognitive burden on user, time wastage, and difficulty in context switching; least number of controllers should be used (a universal controller as a perfect case). Therefore, we investigate culturally familiar controls for the impaired users.

4.3 Quad-directional Button

Nintendo has recently introduced new design for its game controller (Fig. 5). This game has broken the previous records of sales [18] and currently it is at top position (more than 11,450,000 pieces sold till December 31, 2010 [19]) among its traditional rivals; Sony's Xbox 360, and PlayStation 3.

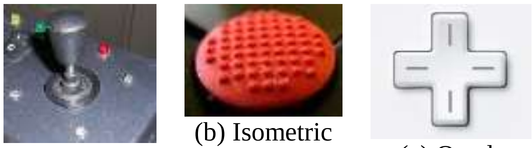
(a) Nintendo Wii set (b) Wiimote in hand. (c) Wiimote quad-directional button.

Fig. 5. Nintendo's Wii video game [20].

Two among other reasons for this huge success are its user friendly 3D flexible controllers, and the low-cost. These controllers have been appreciated by a large number of users. Wiimote has been exercised in the areas other than computer game for example as an assistive device for impaired people using switch controlled software [21], limb action detector [22], 3D unistroke gesture recognition [23], and controlling robots [24]. These studies pointed out the benefits of Wiimote as low cost, easy handling, and availability. To exploit the expertise of game players, especially if they are impaired too, would be a good idea.

6 COMPARISON OF LOGICAL-PHYSICAL MAPPINGS

We investigate the three controls (Fig. 6) according to their logical-physical mappings to find the control with better interaction properties.



(a) Conventional joystick (CJ). (b) Isometric joystick (IJ). (c) Quad-directional button (QDB).

Fig. 6. Three controllers.

The CJ can move/rotate 360^{o}. Assuming that the forward direction corresponds to north, the rest of the directions correspond accordingly. The mappings of CJ and IJ actions with the wheelchair functions are listed in Table 3.

Table 3. CJ and IJ functions with their mappings.

Physical Action of CJ and IJ	Angle	Logical function of Wheelchair
Push forward	90^{o}	Move forward
Push right	0^{o}	Turn right
Push left	180^{o}	Turn left
Pull towards rider	270^{o}	Move back
Stationary/ Unengaged	N/A	Stop
Push forward with right	45^{o}	Nil (Dead zone)
Push forward with left	135^{o}	Nil (Dead zone)
Pull back with left	225^{o}	Nil (Dead zone)
Pull back with right	315^{o}	Nil (Dead zone)
Twist (Only with CJ)	Around 360^{o}	Nil

The rider of the wheelchair can move forward, turn right, turn left, and move back by interacting with (pushing/ pulling) CJ and IJ. On leaving the joysticks at the default position, the wheelchair stops. Table 3 is also listing movements at four angles and twist (only with CJ) that have no functionality associated with them. In fact, none other than first five listed positions, there exists a physical-logical mapping. Whilst the user can move CJ in 356 other angles without any function will only result in poor interaction and may create confusion. Similarly, we study the logical-physical mappings between QDB and the wheelchair. All actions are mapped to their corresponding logical states. In addition to first five primary motions, we have proposed a double press function that is mapped to continuous forward movement of wheelchair to achieve a hands-free experience. The user can press any button or the same forward button to stop the automatic forward movement. This is very important as the design is for impaired people. In existing system, user has to keep holding the joystick in pushed forward position. In case of long distance, users may get tired especially due to impairment. Additionally, this also frees the user arm or hand. This will also facilitate those users having deformed fingers or who may not feel comfortable holding any control for long. The mappings are listed in Table 4.

Table 4. Quad-directional button functions with their mappings.

Physical Action of QDB	Logical Function of Wheelchair
Press forward button	Move Forward
Press right button	Turn right
Press left button	Turn left
Press backward button	Move back
Unengaged	Stop
Double press forward button (Proposed)	Move forward until any other button press

In contrast to both joysticks QDB has strong affordances. Firstly, the button is already in the shape of four directions and the user will understand its functionality by merely looking at the control before touching it. Secondly, the indicator lines on each side of the button are augmenting the affordance. Third aspect with respect to affordance is the concave shape of the button. The four edges have inclined height as compared to the center of the button. This results in intuitive interaction with the button. Moreover, as we are considering people with any type of impairment especially mobility problems, our subjects may include people having problems of hands or fingers for example the leprosy patients. Therefore, IJ and QDB require not more than one finger to operate. Rather, people without any finger can also operate by using any edge of hand, or arm. QDB does not require holding or grasping anything. Moreover, QDB and IJ do not occupy vertical space that may result in hindering with the clothes of rider, and chances of being damaged. There is no need of any separate rod to hold the Wiimote due to its smart size. It can be mounted on the arm of wheelchair easily. There are no screws QDB and IJ in contrast to the existing CJ. QDB has more functional up gradation capacity and flexibility CJ or IJ. The QDB can be programmed by incorporating different commands for single, double and triple press resulting in elimination of separate button requirement.

However, we discuss the design and physicality principles of these controls in the next section to finally decide the best interaction controller for wheelchair.

7 ANALYSING THE DESIGN AND PHYSICALITY PRINCIPLES

It is essential to investigate the design and physicality principles to achieve natural interaction. The common point in various definitions of affordance is that it invites the user to a particular action [17]. However, there are some other aspects, besides affordance, that play significant role in conveying the information about the logical function of the device to the user. The importance of these aspects or states in the design had already proven when we explored the concept of fluidity [26] by investigating the physical and logical relationships [17]. We are briefly discussing only more influential factors in the subsequent subsections.

7.1 Exposed State

The reflection of logical state through physical state is exposed state property. Due to the immediate feedback, the user easily comprehends how to manipulate the control which results in the natural interaction. In QDB, the un-pressed and lifted state of button exposes the off condition, whilst the four sidedness (even in off state) exposes that it is meant to control movement in four directions. A control having exposed state does not require any additional features like markings etc, but quad-directional button has line markings on all four sides for direction indication that further augments the exposed state. Additionally, the concave shape of the button at the center and inclined four edges offer strong affordance for the finger. On the other hand, both CJ and IJ do not have exposed state property.

7.2 Hidden State

The opposite of exposed state is hidden state. Controls having this property lack naturalness. In this case additional decoration is necessary to help the user. In existing system, CJ bears the property of hidden state but there is no decoration present. A direction indicator around the CJ would be appreciated. User does not know what the forward push will result; either it will move the wheelchair forward or backward. Some CJs like the controller of airplane, automatic gear lever of car and controller of caterpillar increase the speed in forward direction by pulling them backwards. CJ's strong cultural influence property at this time, however, helps the user to figure out how to move in, at least, right and left directions. IJ shares the same problem with CJ. QDB does not have this property.

7.3 Directness of Effect

Effect is directly proportional to the action performed. In our case, all CJ, IJ and QDB have fixed logical states; either on or off but both joysticks provide availability of more physical movement than the quad-directional button resulting in confusion due to the property of directness of effect. CJ user may push more than desired whilst IJ user may not move the control at all but the wheelchair will move at constant speed. QDB does not offer such extremes of physical movement hence user gets the feel of go or selection right after the press. This property will result in more natural interaction.

7.4 Locality of Effect

The result of an action should be there and then. But CJ as compared to IJ and QDB has more physical movement domain. It takes considerable time, when user starts pushing or pulling from the initial position to the last physical limit, to establish the mapping between both states. Approximately close to the physical limit a meager sound of 'tick' is produced that represents that 'now' the connection has established and the wheelchair moves. Such behaviour is absent in QDB representing strong locality of effect. This is one of the reasons behind the fact that double-click or double-press action is more natural with QDB than with any joystick.

7.5 Bounce Back

A control having bounce back effect maintains a state until operated then either stays or returns back to its initial physical state, for example, push button. QDB supports stronger bounce back property than both joysticks. Bounce back has two clear states; pressed or in, and un-pressed or out. Pressed state is a transient state; it only stays in this state until a force like finger is pressing it. At this moment our body becomes part of the interaction that is also called embodiment. As soon as the pressure is released, it bounces back to the out state. The affected factors within bounce back are; is the bounce back visible or not; in case of invisible, is it felt or not; when the control is pressed; how long it remain pressed; when the state transition occurred physically as well as logically; are the transitions – physical and logical – mapped with each other; how much time it took in transient state after pressure is released; will it continue performing during this time too; how much time it takes to return back to its initial state; does the returning stroke has some functionality attached to it too; at the end of one press after how much time it is ready to be pressed again to successfully perform the same functionality one more time? CJ and QDB have visible bounce back affect whilst IJ has invisible bounce back affect that can be felt only. Appropriate use of bounce back effect results in natural interaction otherwise produces confusion, as in the case of CJ of wheelchair.

7.6 Physical Requirement

Physical requirement is the amount of physical effort that is needed to perform an operation while interacting with a control or device. We need to remove extra effort and/or movement if the goal can be achieved with less effort according to the requirements. For example, a gear lever or a long joystick like control is used to change gear of an automobile. In manual transmission, five forward gears means driver has to interact with the gear lever more often. The automatic transmission cars are not bound to frequent gear shifting. Therefore, it is wise enough to replace a big control like long gear lever, requiring more effort and movement, with a smaller control. Many car manufacturers have addressed this problem, for example the latest Jaguar XKR, model 2010 has replaced the gear lever with a dial. During normal forward driving there is seldom requirement to use this control. The benefits of using such control instead of conventional large levers are many; reducing the extra effort, force and movement, saving the work-space for user (that is especially important inside a car having all other compact controls), reducing the chances of damage, increasing the life of control and may provide support for additional feedback (LEDs in Jaguar’s example). This is the reason why a steering wheel is not appreciated on an impaired person’s wheelchair. What is the need of putting extra effort if the task can be accomplished with lesser effort? Moreover, we are proposing the solution for impaired, where the requirement is to put minimum effort for achieving maximum results. Therefore, both IJ and QDB are better than CJ in this aspect.

7.7 Mental Requirement

Exposed state falls into lower sub-conscious category whilst the hidden state falls into low-level cognition category of mental requirements.

The tasks under sub-conscious category are natural to undertake with no burden of cognition and hence intuitive whilst low-level cognition requires some mental processing and storage. Therefore, the quad-directional button requires least cognition. The complete comparison is outlined in Table 5.

Table 5. Comparison between CJ, IJ, and QDB according to design and physicality principles.

Design and Physicality Principle	**CJ**	**IJ**	**QDB**
Exposed state	✕	✕	✔
Hidden state	✔	✔	✕
Directness of effect	Creates confusion	Creates confusion	No confusion
Locality of effect	Weak	Strong	Strong
Controlled state	✕	✕	✕
Tangible transition	✔	✕	✔
Visible bounce back	Weak	✕	Strong
Tactile bounce back	✕	✔	✕
Inverse action	✔	Weak	✔
Compliant interaction	✕	✕	✕
Affordance	Weak	✕	Strong
Cultural influence	Strong	Moderate	Strong
Mental requirement	Low-level cognitive	Low-level cognitive	Sub-conscious
Physical requirement	High	Low	Low

Both CJ and QDB have strong cultural influences, and share the aspects of tangible transition and inverse action whilst IJ does not support tangible transition and holds weak inverse action property. Therefore, Wiimote's QDB is the preferred control over CJ and IJ as wheelchair controller according to design and physicality principles. The proposed additional functionality of hands-free motion (with double press) further enhances the performance.

8 DISCUSSIONS AND CONCLUSION

Currently, the interaction with the UI of wheelchair controller is suffering from various limitations. It can be improved considerably by investigating them according to design and physicality principles, and improving the physical-logical mappings. This has not been exercised before on the wheelchair controller using isometric joystick and Wiimote's quad-directional button according to design and physicality principles. In addition to highlighting the limitations of existing system's conventional joystick, we have also proposed new functionalities like hands-free movement to make the operation by impaired people not just easy but enjoyable.

In this work, we have investigated the existing problems in a wheelchair interface design and proposed a novel natural interface design for the disable wheelchair users. It has many advantages over existing system including dual-mode availability (input & output), least operational requirement for input and output, easy operational method, flexibility, minimum space requirements especially vertical, no risk of sticking with clothes during operation, and no risk of damage. We have tried to provide some guidelines for developers especially embedded software engineers to help them in considering usability and naturalness of interaction during development. We are planning to further study these controls and enhance the interface design by performing comprehensive usability evaluation on impaired users.

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10 REFERENCES

1. Dix, A., Ghazali, M., Ramduny-Ellis, D.: Modelling Devices for Natural Interaction. Electronic Notes in Theoretical Computer Science, pp. 23--40 (2008).
2. Ghazali, M., Dix, A.: Visceral Interaction. In The British Computer Society. Proceedings of BCS-HCI. Edinburgh, Scotland, pp. 68--72 (2005).
3. Norman, D.: The next UI breakthrough, part 2: Physicality. Interactions vol. 14, issue 4, pp. 46--47 (2007).
4. Sharp, H., Robinson, H., Petre, M.: The Role of Physical Artefacts in Agile Software Development: Two Complementary Perspectives, Interacting with Computers, vol. 21, issues 1-2, Special issue: Enactive Interfaces, pp. 108--116 (2009).
5. Nomura, S., Hutchins, E., Holder, B.E.: The Uses of Paper in Commercial Airline Flight Operations. In: Proceedings of CSCW 06, pp. 249--258 (2006).
6. Sellen, A.J., Harper, R.H.R.: The Myth of the Paperless Office. The MIT Press (2003).
7. IterEx. http://www.planningcards.com/site/
8. Bujnowski, A., Drozd, M., Kowalik, R., Wtorek, J.: A Tactile System for Informing the Blind on Direction of a Walk, Conference on Human System Interactions, pp. 893--897 (2008).
9. Hara, M., Shokur, S., Yamamoto, A., Higuchi, T., Gassert, R., Bleuler, H.: Virtual Environment to Evaluate Multimodal Feedback Strategies for Augmented Navigation of the Visually Impaired, Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), pp. 975--978 (2010).
10. Shah, C., Bouzit, M., Youssef, M., Vasquez, L.: Evaluation of RU-Netra - Tactile Feedback Navigation System for the Visually Impaired, International Workshop on Virtual Rehabilitation. pp. 72-77 (2006).
11. Ivanchenko, V., Coughlan, J., Gerrey, W., Shen, H.: Computer Vision-based Clear Path Guidance for Blind Wheelchair Users. In: Proceedings of the 10th international ACM SIGACCESS conference on Computers and accessibility (Assets '08). pp. 291--292. ACM, New York (2008).
12. Kuno, Y., Yoshimura, T., Mitani, M., Nakamura, A.: Robotic Wheelchair Looking at All People with Multiple Sensors. In: Proceedings of IEEE International Conference Multisensor Fusion and Integration for Intelligent Systems, pp. 341--346 (2003).
13. Abascal, J., Cagigas, D., Garay-Vitoria, N., Gardeazabal, L.: Mobile Interface for a Smart Wheelchair. In: 4th International Symposium on Mobile Human-Computer Interaction (Mobile HCI '02), Springer-Verlag, London, UK, pp. 373--377 (2002).
14. Home Care Specialists Inc. http://www.homecarespecialistsinc.com/medical_equipment.html
15. Sabil, S., Jawawi, D.N.A.: MARMOT and PECOS Hybrid Approach for Embedded Real Time Software Development, The 5th International Conference on Information & Communication Technology and Systems (ICTS) 2009, Surabaya, Indonesia (2009).
16. Dix, A., Ghazali, M., Gill, S., Hare, J. Ramduny-Ellis, D.: Physigrams: Modelling Devices for Natural Interaction. Formal Aspects of Computing, vol. 21, issue 6, pp. 613 (2009).
17. Ghazali, M.: Discovering Natural Interaction of Physical Qualities to Design Fluid Interaction for Novel Devices. Research Monograph, Universiti Teknologi Malaysia (2007).

18. Ebay, http://reviews.ebay.com/A-Comparison-of-Xbox-360-PlayStation-3-Nintendo-Wii_W0QQugidZ10000000003580375
19. Tech Watch, http://www.techwatch.co.uk/2010/10/04/one-in-three-uk-households-own-a-nintendo-wii/
20. Game Spot Asia, http://asia.gamespot.com/users/MushroomWig/show_blog_entry.php? topic_id=m-100-25803446
21. Standen, P.J., Camm, C., Battersby, S., Brown, D.J., Harrison, M.: An Evaluation of the Wii Nunchuk as an Alternative Assistive Device for People with Intellectual and Physical Disabilities Using Switch Controlled Software, Computers & Education, Serious Games, vol. 56, issue 1, pp. 2--10 (2011).
22. Shih, C., Chang, M., Shih, C.: A Limb Action Detector Enabling People with Multiple Disabilities to Control Environmental Stimulation Through Limb Action with a Nintendo Wii Remote Controller, Research in Developmental Disabilities, vol. 31, issue 5, pp 1047--1053 (2010).
23. Raza, S.A., Ahmed, M.W., Madni, T.M., Tahir, M., Khan, M.I., Ashraf. M.: Preliminary Evaluation of 3D Unistroke Gestures: An Accelerometer-based Approach, IEEE ICIIT, University of Central Punjab, vol. 1, pp. 634--638. Lahore, Pakistan (2010).
24. Olufs, S., Vincze, M.: Simple Inexpensive Interface for Robots Using the Nintendo Wii Controller. In: Proceedings of the 2009 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS'09). pp. 473--479. IEEE Press, Piscataway, New Jersey (2009).
25. Kim, W.Y., Son, H.S., Kim, R.Y.C., Jeon, B.K.: User Behavior Analysis Framework (UBAF): Mapping HCI with SE. In: Future Generation Communication and Networking (FGCN '07), vol. 2, pp. 565--568. IEEE Computer Society, Washington DC, USA (2007).
26. Dix, A., Finlay J. Abowd, G., Beale R.: Human-Computer Interaction. Third Edition. Prentice Hall (2004).
27. Dicianno, B.E., Cooper, R.A., Coltellaro, J.: Joystick Control for Powered Mobility: Current State of Technology and Future Directions. Physical Medicine and Rehabilitation Clinics of North America, vol. 21, issue 1, pp. 79--86 (2010).
28. Wang, E.M.Y., Shih S.S.Y.: A Study on Thumb and Index Finger Operated Interface for Personal Mobile Devices: Mobile Phone Keypad and Joystick. Industrial Engineering and Engineering Management, 2009. IE&EM '09. 16th International Conference (2009).
29. Cooper, R.A., Spaeth, D.M., Jones, D.K., Boninger, M.L., Fitzgerald, S.G., Guo, S.: Comparison of Virtual and Real Electric Powered Wheelchair Driving Using a Position Sensing Joystick and an Isometric Joystick. Medical Engineering & Physics, vol. 24, issue 10, pp. 70--708 (2002).
30. Zhai, S., Smith, B.A., Selker, T.: Improving Browsing Performance: A Study of Four Input Devices for Scrolling and Pointing Tasks. In Proceedings of the IFIP TC13 Interantional Conference on Human-Computer Interaction (INTERACT '97), Steve Howard, Judy Hammond, and Gitte Lindgaard (Eds.). Chapman & Hall, Ltd., London, UK, UK, 286-293 (1997).
31. Wobbrock, J.O., Chau, D.H., Myers, B.A.: An Alternative to Push, Press, and Tap-tap-tap: Gesturing on an Isometric Joystick for Mobile Phone Text Entry. Proceedings of the SIGCHI conference on Human factors in computing systems. San Jose, California, USA, ACM**:** pp. 667—676 (2007).
32. Duran, L., Fernandez-Carmona, M., Urdiales, C., Peula, J., Sandoval, F.: Conventional Joystick vs. Wiimote for Holonomic Wheelchair Control, Bio-Inspired Systems: Computational and Ambient Intelligence. J. Cabestany, F. Sandoval, A. Prieto and J. Corchado, Springer Berlin / Heidelberg, pp. 1153--1160 (2009).
33. Zhai, S. Human Performance in Six Degree of Freedom Input Control. Univ. of Toronto; Thesis, Graduate Dept. of Industrial Engineering (1995).
34. Rao, R.S., Seliktar, R., Rahman, T., Benvenuto, P.: Evaluation of an Isometric Joystick as an Interface Device for Children with CP. RESNA Press; Arlington, VA, pp. 327--329 (1997).
35. Rao, R.S., Seliktar, R., Rahman, T.: Evaluation of an Isometric and a Position Joystick in a Target Acquisition Task for Individuals with Cerebral Palsy. IEEE Trans Rehabil Eng, vol. 8, issue 1, pp. 118--125 (2000).

36. Stewart, H., Noble, G., Seeger, B.: Isometric Joystick: A Study of Control by Adolescents and Young Adults with Cerebral Palsy. The Australian Occupational Therapy Journal, vol. 39, issue 1, pp. 33--39 (1991).
37. Pellegrini, N., Guillon, B., Prigent, H.: Optimization of Power Wheelchair Control for Patients with Severe Duchenne Muscular Dystrophy. Neuromuscular Disorder, vol. 14, issue 5, pp. 297--300 (2004).