Verification of Improvements in Usability and Safety by Implementing CC Switch to Touch Screen Displays

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ABSTRACT – Today, touch screen display is being widely used in various fields for its attractive direct-manipulation approach. However, there still lie many disadvantages in operation of a touch screen display due to lack of tactile feedback. To improve and overcome the uneasy operation of touch screen display, we proposed a new concept switch named CC Switch that provides positive tactile feedback on a display. CC Switch was presented at the 12th Symposium on Human Interface in 1996 and 7th International conference on Human-Computer Interaction in 1997.[1], [2] Since its introduction, CC Switch has been applied to fields of various industries such as automobile production line, semiconductor production line, broadcasting system, industrial robot, and other factory floor applications. This paper reports the effectiveness of CC Switch on improving the uneasy operation of touch screen display and the results of user survey performed.

Keywords: CC Switch, Touch Screen Display, Tactile Feedback, Usability, Safety,

1. Introduction

Among varieties of Human-Machine Interfaces, interactive displays consisting of a touch screen arranged on an LCD (Liquid Crystal Display), i.e. touch screen displays, are widely used as a GUI (Graphical User Interface) in varieties of applications where users want to make direct-control touches on the screen with a finger. Many studies have been performed to investigate the usability of touch screen displays.[3], [4], [5], [6] Since these interactive displays make it possible to arrange many virtual components on a screen and to show messages and graphical data, this provides greater functionality and flexiblity for operators. However, these conventional interactive displays still have many disadvantages in actuator function of control switches from the viewpoint of usability and safety based on ergonomics. One key disadvantage is that the touch screen is easily actuated with a light touch on the display screen. This produces operator uncertainty as follows; (1) unlike mechanical pushbutton switches, lack of physical movement and tactile feedback causes uncertainty, (2) inadvertent operation occurs frequently because the touch screen is actuated when the operator slightly touches the screen by mistake, (3) finger tracing is impossible because a light touch actuates the touch screen, (4) identifying the right button is difficult because it is hard to find where to press unless operator looks at the screen taking his eyes off the operating machinery, and (5) quick operation is many times impossible in case of emergency due to layer structure of the graphics.

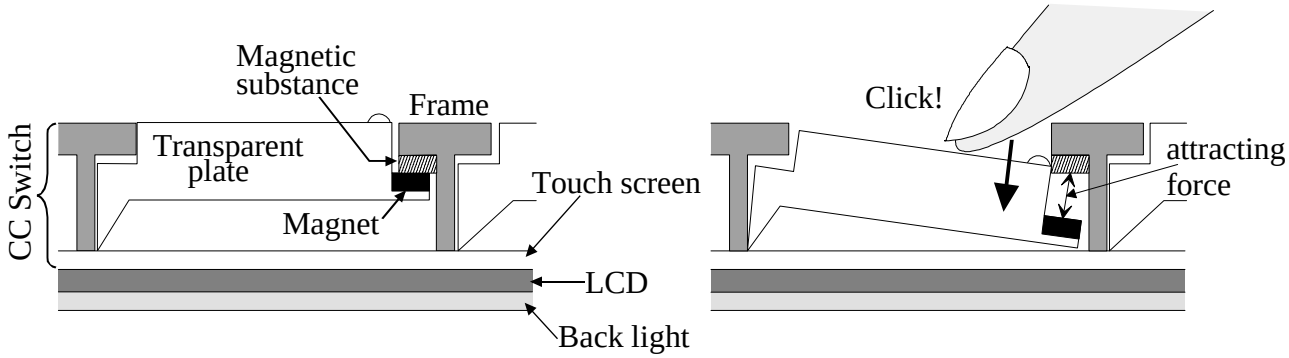
In order to overcome these issues, we have already made reports on improvements of operation and advantages of CC Switch implemented display from ergonomic view.[7], [8], [9], [10], [11] In this paper and from user surveys, we report the effectiveness of CC Switch. It should be noted that CC Switch complies with all major international standards.

2. Overview of CC Switch

2.1 Structure and switching characteristics

Figure 1 shows the structure and operation principle of CC Switch. CC Switch consists of a transparent plate, a frame that supports the transparent plate, a magnet, a magnetic substance and a touch screen. The transparent plate and frame are placed on top of a touch screen display. A magnet is embedded on one side of the transparent plate and a magnetic substance is attached on the frame. The switching operation of CC Switch is made by the simple, but effective attracting force between the magnet and magnetic substance as indicated in figure 1(b). Between transparent plate and touch screen there is a space gap of 0.6mm, which is the switching stroke. The graphical button displayed on the screen is sized to the dimension of each CC Switch, which make correspondence with the graphical button displayed and the CC Switch above it.

Figure 2 shows the switching characteristics of CC Switch in comparison with touch screen and conventional tactile switch. The switching characteristics are expressed by the stroke on the horizontal axis, and load, which shows how much pressure is applied to the switch, on the vertical axis.



(a) CC Switch is in “OFF” condition (b) CC Switch is in “ON” condition

Figure 1. Structure of CC Switch

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The square symbol in figures 2(a), (b) and (c) represent the 'switch on' point of each switch.

The operation of CC Switch is expressed by figure 2(b). First, if the operator wishes to switch a desired CC Switch, some pressure must be applied to the transparent plate (region 'I' in figure 2(b)). Then if the operator applies enough pressure so that it exceeds the attracting force between the magnet and the magnetic substance, the transparent plate suddenly starts to move towards the touch screen making the operator feel a 'click' sense of touch (region 'II' in figure 2(b)). When the transparent plate hits the touch screen, the touch screen is switched on (region 'III' in figure 2(b)). During this transition, the operator will feel a 'click' sense of touch and stroke in the operation of CC Switch similar to those of operating a conventional tactile switch. Moreover, with CC Switch the operator can trace the buttons by finger without activating the switch allowing positive identification before pressing the switch.

As is clear from figure 2(a), touch screen shows monotonous increase of load and limited stroke. This can cause unintentional input since no tactile feedback occurs. On the other hand, CC Switch shown in figure 2(b) shows a different switching curve compared to touch screen. It shows the maximum and minimum points that enable the operator to feel the 'click' (tactile feedback) when the load decreases from the maximum to minimum point. In addition, the operator can feel the 'stroke' with CC switch. The switching characteristic of a conventional tactile switch is shown in figure 2(c) and it is similar to that of CC Switch. Therefore, CC Switch enables the operator to feel click tactile feedback as provided by a conventional switch.

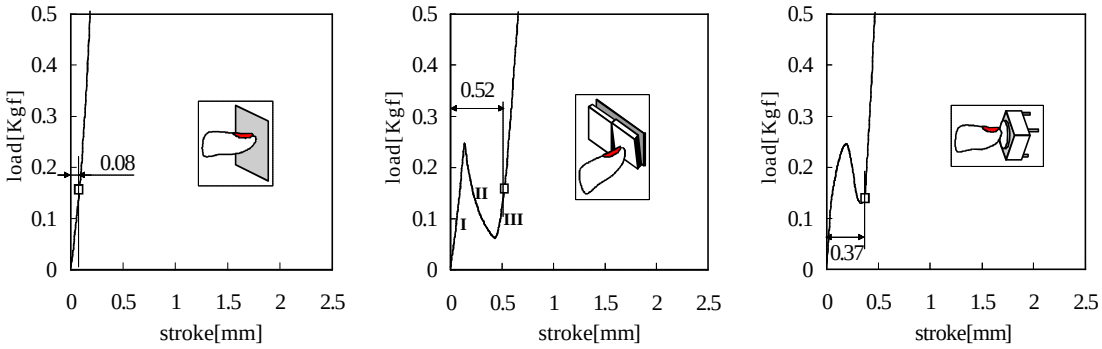
2.2 Characteristics of GUI, SUI and SUI on GUI

Classifying user interface into Graphical User Interface (GUI) and Solid User Interface (SUI) was proposed in 1996. [12] GUI is a method, which virtual buttons and figures displayed on a screen are activated. Popular GUI device is a touch screen display. SUI is a method, which mechanically constructed pushbutton switches are activated. CC Switch implemented display is a new device that combines GUI and SUI and it can be categorized as a SUI on GUI device. Comparison of characteristics among GUI, SUI and SUI on GUI device, i.e., touch screen, push buttons and CC Switch is shown in table 1. [8], [9], [10]

Here we classified the characteristics of each device into operation and function. GUI can display graphical information and has a variety of functions. On the other hand, pushbutton switches, as a SUI device is superior in its operation. CC Switch implemented display is a device that has SUI on GUI. Therefore, advantages of both SUI and GUI are combined. These three devices are selected according to the necessities of the applications and in most of the case they coexist.

3. APPLICATONS OF CC SWITCH

Tables 2 shows part of the applications that CC Switch implemented displays are utilized. Areas of applications are in a wide range where their usage requires operational safety. Displays with CC Switch can be largely classified into panel mount type and mobile pendant type. For this discussion, panel mount type means displays that are used in fixed place as shown in figure 3(a) type I and type II, and mobile pendant



(a) Touch screen (b) CC Switch (c) Tactile Switch

Figure 2. Switching characteristics of switches(indicates switch on point)

Table 1. Characteristics of GUI, SUI and SUI on GUI (O: good, X: no good)

Characteristics		(a) GUI 	(b) SUI on GUI 	(c) SUI 
Operation (Usability)	Tactile feedback exists?	X	O	O
	Finger tracing of the buttons possible?	X	O	O
	Unintentional mis-operation avoided?	X	O	O
	Secure operation enabled?	X	O	O
	Able to identify and operate the buttons without looking at them?	X	O	O
Function (Utility)	Information displayed	Text message, Graphics	Text message, Graphics	Text, Numbers
	Amount of information	Large	Large	Limited
	Information displaying method	Hierarchical	Hierarchical	Limited

Table 2. Applications of CC Switch implemented displays

Applications	Typical Usages
Machine control	Industrial robot, Laser welding machine, Tooling machine, Conveyer system , CNC machine, Assembling machine, Plastic molding machine, Press machine, Parts feeder, Wire bonding machine, Cleaning machine, Control panel for various machines, etc.
Factory Automation and Production Lines	Automobile production lines(Body welding lines, Engine assembling, Body assembling, Gantry loader, etc), Semiconductor production lines, LCD production lines, CD/DVD production lines, Optical lens production, Food production lines, Beer production lines, etc.
Industrial Application	Ticket vending machine, Automated warehouse system, Waste water treatment system, Thermal treatment system, Construction control machine, Parking lot control system, Restaurant guiding system, etc.
Communication System and Building Automation	Building entry security system, Facility Lighting control system, Audio control system, Broadcasting control system, Communication Monitoring System, Studio and stage control system, etc.

type means displays that the operator holds in their hands as shown in figure 3(b). Panel mount type and mobile pendant type displays are used according to the requirements of the application.

Having the displaying ability of GUI device, CC Switch implemented display can display multiple screens in a hierarchical structure. By displaying buttons corresponding to each CC Switch for each screen, hierarchical screens will be selectable by CC Switch. This capability makes CC Switch functions as a variable function key. This is equivalent to the usual function keys F1, F2, F3, etc. as those used on a PC keyboard. When the function of the function keys change, it is difficult for the operator to determine what key corresponds to what function, whereas with CC Switch this is not the case. With the change of the screen, the displayed button also changes so that the operator will know clearly the function of each CC Switch.

4. RESULTS OF USER SURVEY

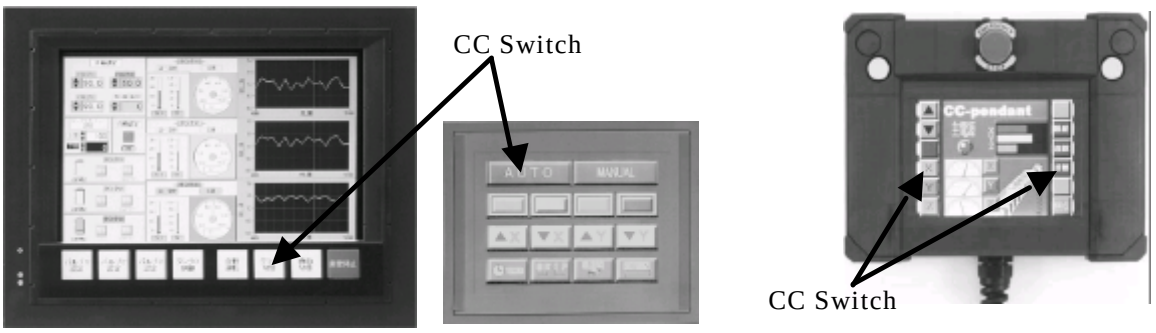
Figure 4 shows the annual growth of number of CC Switch installed. The number of CC Switch installed is classified by panel mount type display (figure 3(a)) and mobile pendant type display (figure 3(b)). From the time we introduced CC Switch to the market, the number of CC Switch installed has grown each year and has reached 114 thousand in total. Today the amount of CC Switch installed on panel mount type and mobile pendant type display is becoming nearly equal. These results show that the importance of click tactile feedback of CC Switch is being recognized in many applications. Based on multiple applications it is important to analyze the button configuration of CC Switch aiming at standardization. The results of the survey are shown in figure 5.

The configuration for panel mount type display shown in figure 5(a) can be classified into two types. One is CC Switch as part of the display, indicated as type I. The other is CC Switch on the whole display indicated as type II. For type I display there are three types of CC Switch configurations, those on the bottom one row, bottom two rows, and two columns on right and left of the display. CC Switch in type I display is used as variable function keys, and rest of the screen as GUI. On the other hand, type II display, which holds 60% of the share, has various CC Switch configurations. The three configurations shown in figure 5(a) are the top three configurations in amount installed. Type II display is used when the user needs many selectable and variable function switches.

The CC Switch configuration for mobile pendant type display is shown in figure 5(b). It is interesting to see that with panel mount display there are varieties of CC Switch configuration, whereas with mobile pendant type display there are only two. This is because the CC Switch on mobile pendant type displays is held in the operator's hand and operation by the thumb is natural. Therefore, CC Switch on mobile pendant type display is configured to the area of the screen where operator's thumb can reach and easily operate. The advantage of this CC Switch configuration is that the operator can trace the CC Switch with a thumb while looking at the target machine being controlled, without looking at the CC Switch implemented display.

5. CONCLUSION

As reported here, CC Switch as SUI on GUI is a new way to improve the usability and safety of touch screens and has been proved by many industrial applications that require safety operation. In the Human-Machine Interface environment such as the FA (factory automation) and many other applications where operators and machines cooperate, improvement of safety for operators is indispensable. This can be confirmed by the international safety standard ISO 12100, which is currently under deliberation as an international standard of safety, which stipulates a clause of ergonomic principles for operators when operating a machine as follows.



Type I Type II

(a) Panel mount type (b) Mobile pendant type

Figure 3. CC Switch implemented displays

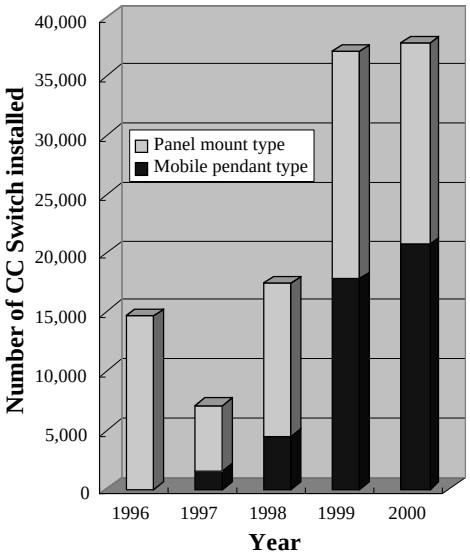


Figure 4. Growth of number of CC Switch installed

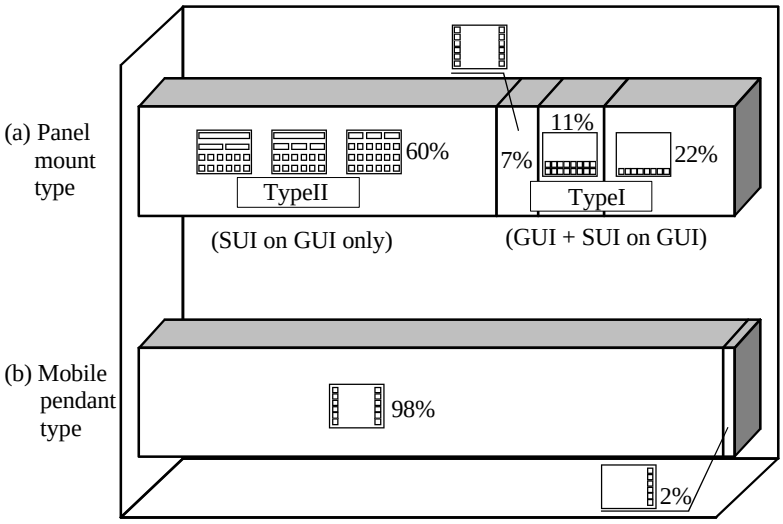


Figure 5. Configuration of CC Switch on a display

3.6 Observing ergonomic principles:

All elements of the "operator-machine" interface such as controls, signaling or data display elements shall be designed in such a way that clear and unambiguous interaction between the operator and the machine is possible.

3.6.6 Designing, locating, and identifying manual controls (actuators) so that:

They can be safely operated without hesitation or loss of time and without ambiguity (e.g. a standard layout of controls reduces the possibility of error when an operator changes from a machine to another one of similar type having the same pattern of operation).

Controls shall be so arranged that their layout, travel and resistance to operation are compatible with the action to be performed, taking account of ergonomic principles.

These clauses state that the elements of the Human-Machine Interface should be designed so that the operator can clearly understand their meaning and function, and that the layout of the elements should be designed so that the possibility of error in operating the elements would be the least. For example, the 'QWERTY' key layout of PC keyboard is standardized for virtually all manufactures, and therefor users experience no difficulties when changing from one to another. In the same way, we believe that standardizing the layout of CC Switch is also important and will pursue this further.

Finally, judging from these clauses, CC Switch is a good solution in satisfying these demands by means of safe and clear operation, and we should further apply this technology to more industrial applications.

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