

A New Approach to Operating Machines with High Functionality

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Abstract

This paper presents the necessity and the concept of a new approach to control-units for technical devices with high functionality.

Due to the increasing contact of humans with technical devices in everyday life and the growing complexity of these devices, the man-machine communication gains in importance. The state of the art man-machine interfaces to operate complex technical devices are conventional push-buttons and touch-screens. Because both lack in either flexibility and clarity, or in haptic feedback, investigations about new solutions are necessary.

The approach presented is characterized by a flat control-panel, where buttons can arise in variable configurations. The buttons are programmable in size and haptic properties. The panel will comprise of single segments, each of them consisting of an actuator and a position sensor, which are currently in development.

The requirements, possibilities, and difficulties of this approach are discussed.

1. Introduction

The communication between man and machine nowadays gains in importance. On the one hand people are more often in contact with technical systems in everyday life. Transportation, communication, professional and leisure-time activities are almost unthinkable without using technical devices. On the other hand these devices keep on increasing their number of features. The success of modern microelectronics enables the implementation of additional functionality with almost no additional costs [1]. In summary there is a trend towards technical devices becoming more powerful and complex.

2. Problem

Unfortunately the increase of functionality does not imply only advantages for the user, especially with regard to the man-machine interface. The additional features have to be selected and controlled by the user, what often

changes the usability of the device for the worse. People suffer from “feature shock”, meaning they are unable to use the functionality due to the difficulty in operating the machine. This is a serious problem, as the features of devices from competing companies grow closer together, and therefore the man-machine interface becomes decisive for sales [2].

2.1 Conventional solution

There are two common ways to handle the high functionality of technical devices. One possibility is to provide a huge control panel with a lot of buttons and switches. Besides the drawback of a confusing appearance of such a panel, the available space for the control unit limits this solution. In order to be used by human fingers, every single control element, like a push-button, must not fall below a certain size.

Another more promising way to handle the large amount of features is with the use of touch-screens. The touch sensitive displays offer the opportunity of a menu-driven handling, similar to what is used in computer software. The menu structure is based upon the idea of not offering all selectable functions at once, but to divide them into different levels. Therefore a lot of functions can be offered by displaying only a manageable number of control elements. Today touch-screens are already often used for pda’s, ticket-machines, cash-dispensers etc.

The major disadvantage of touch-screens is the missing haptic-feedback, that ordinary push-buttons provide in contrast to the virtual push-buttons of touch-screens. This results in an unexpected perception during the operation. People are used to feel the contact between the finger and the control element, the force exerted by the button to the finger, the movement during the depressing, and the haptic “click” when the electric contact is closed. These sensations form the basis for using control elements in an intuitive and automatic way without the need of attention [3]. As the user only pushes on a rigid screen made of glass while using a touch-screen, the operation does not happen intuitively. Figure 1 depicts the differences of the information flow between using a conventional push-button and a touch-screen.

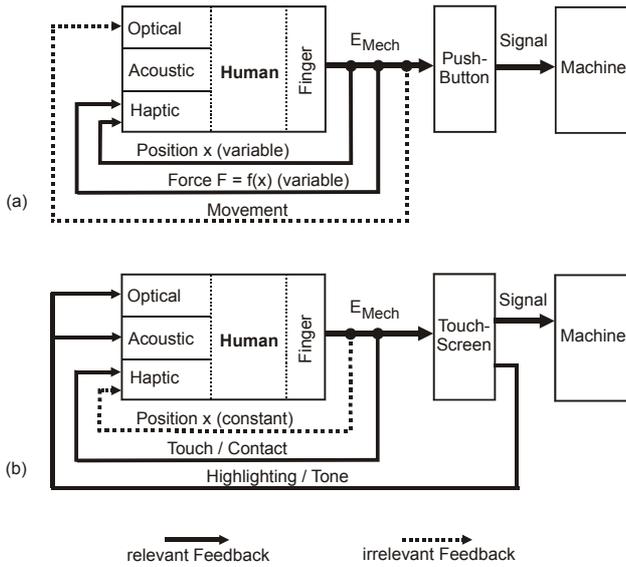


Figure 1. Comparison of the sensory feedback while using (a) a conventional push-button and (b) a touch-screen. The position and exerted force (mechanical impedance) of the push-button change during depressing, which is sensed by the haptic channel. The rigid touch-screen provides only a haptic sensation of the contact between finger and screen. An additional feedback to another sensory organ has to be generated artificially to confirm the operation of the virtual button on the screen.

Even if people are able to learn new patterns of behaviour for controlling machines by a lot of training, it is questionable if the human should be forced to do so, especially if elderly people have to use these machines (e.g. ticket-machine) too. We think that new technology should adapt to the human, not vice versa. This view is also stated by other authors [4].

3. New approach

As haptic feedback is expected by the user and helpful for intuitive machine operation, it appears reasonable to investigate the haptic aspect in man-machine communication. The claim for haptic feedback during the operation of machines in order to prevent uncertainty and enable fast and comfortable controlling is mentioned by several authors [5][6][7]. Therefore we are working on a new approach to operate the enormous functionality of modern technical devices without neglect of the haptic requirements. The solution seems to be a combination of both the flexibility of touch-screens and the haptic stimuli of ordinary push-buttons.

We envisage a flexible control-panel that is able to offer different numbers of buttons, which are – in contrast to the virtual buttons on touch-screens – indeed to be pressed down by the user similar to conventional push-buttons. Depending on the current situation or level of the menu-structure, the control panel is able to generate the

required number of buttons with programmable shape and size.

3.1 Concept and applications

The concept of a flexible control-panel with haptic feedback can be realized as follows: Imagine a flat area consisting of many single segments, which can arise independently from each other as illustrated in figure 2. In this way different numbers of buttons with variable forms and sizes can be generated. With a specific controlling the buttons can put up a resistance when pressed down by the user. Thus a menu-driven handling with adequate haptic feedback is possible.

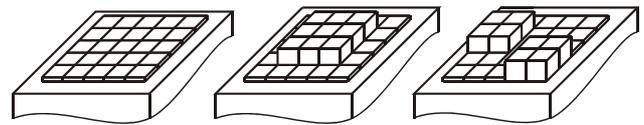


Figure 2. Sketch of a control-panel with buttons variable in number and size. The panel comprises of single segments.

The range of control-panels designed in this way is very wide. In many cases they could substitute touch-screens. But even new applications can be imagined. A universal remote control for TV-set, video-recorder, satellite-receiver and so on could be designed, that offers for every device just the accessory control-elements. Such a remote control differs from other universal controls on the market in its clear arrangement of the buttons.

Moreover the force exerted by the buttons of the described control-panel is variable, as the conditions of the segments are programmable. So for instance an user specific adaptation is conceivable. Depending on the user's desire, more or less force is needed to press the buttons down. Another possibility is to adapt the characteristic of a button to its function. For example the more important or serious the launch of a function is, the more force is needed to push the referring button down. Additionally some more information can be transferred to the user with a special behaviour like vibrations of the buttons. An event like a malfunction can be indicated in this way.

4. State of the project and further tasks

In order to demonstrate the advantages and performance of the concept presented, a control-panel for testing purposes should be developed.

Currently the design of the segments, which will finally form the control-panel, is in progress. As the position and the exerted force of the segments have to be controlled, every single segment is a system consisting of an actuator and a sensor.

In order to ensure a wide range of different programmable combinations of buttons with various shapes, the

dimensions of the segments should be relatively small. For the demonstration system the mechanical design should not exceed a maximum size of 1x1 cm² per segment. Besides the limited space, the actuator needs to show some more important performance characteristics. A minimum pressure of 20 mN/mm² is required to create a unique haptic impression during the depressing. So a button of the size of 1 cm² can exert a force of 2 N, which is an average value of conventional push-buttons.

Several authors discuss the force output resolution for force feedback devices. According to SRINIVASAN [8] a resolution of 0,01 N is necessary to make full use of human haptic capabilities, whereas SHIMOGA [9] recommends 0,05 N, respectively 0,02 N/cm².

The stroke of the actuator has to be at least 5 mm. This is not so much necessary for the haptic impression, as to ensure a visible difference between an inactive and an active, which means extended, segment.

The choice of possible actuators is strongly limited by these constraints. On closer examination only an electrodynamic actuator seems to fulfil the demands. Moreover such an actuator has the advantage of a linear relation between the active current and the exerted force. This enables a system without force sensors, as the force can be calculated if the current is known.

As the realised control-panel should provide buttons with an appropriate haptic feedback, the exerted force must not be constant during the depressing. There is the need for a rising resistance until the button switches, afterwards a decrease. This characteristic behaviour is called "haptic click" and supports an intuitive operation [5]. In order to provide such behaviour, the position of the segments need to be measured by a sensor.

Similar to the design of the actuator, the sensor design has to be adapted to the human haptic capabilities. Although the threshold to detect static height differences by skin deformation at the human fingertip is 10 µm [10], ROSENBERG advises a position resolution of 25 µm [11] for a high quality force feedback system. Further the size of the sensor should not exceed the dimensions of the actuator. With respect to cost efficiency, an optical sensor, which evaluates reflecting light of an infrared light-emitting diode, will be used for the first conception.

After completing the design of the actuator and the sensor, a prototype of a single segment has to be fabricated. An evaluation referring to the mechanical and electrical behaviour will show whether a redesign is necessary. If the resolution of the exerted force and of the measured position matches the expectations, the next step is to compose an array consisting of several segments. The mechanical design of this array requires much development effort, as a modular concept is preferred to enable a simple assembly and serviceable operation.

Beside the mechanic and electronic development of the actuator-sensor-system, investigations about the controlling have to be done. Depending on the desired appear-

ance of the new created control-panel, the array has to be configured in such a way, that the correct number of buttons arises with the expected size and location. Therefore the stroke and exerted force of every single segment has to be controlled independently from other segments.

A major challenge is to provide a uniform movement of all segments forming one of those buttons, even if not all segments are touched and therefore depressed by the user's finger. Otherwise the button would not visually appear as a self-contained unit. This would confuse the user.

Finally the prototype of the new approach to control-units has to be evaluated by thorough investigations. Both the technical performance and the usability for everyday applications have to be checked.

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