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Advanced Remote With HAPTIC

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ABSTRACT

We introduce a new universal remote control that gives easy-to-control interface for home devices such as TV, video/audio player, room lighting and temperature control. In order to use conventional remote controls, people need to understand complex instruction manuals and remember functions assigned to buttons. In addition, the button-based control does not provide an intuitive interface so the user presses a button several times to browse information and has difficulty in searching the right button among many buttons. Our universal remote control addresses these limitations by using a touch screen, a force-feedback dialknob, and two buttons instead of many buttons. We suggest an example scenario to interact with a conventional TV set, oomlighting, and air conditioner using our universal remote control. The result of a user study to evaluate the usability of the device shows that the universal remote control is very efficient and intuitive interface to control customer electronicsdevices1.

Key words: **Universal Remote Control, Haptic Interface, Home device.**

I. INTRODUCTION

Usually home appliances such as TV, radio, video/audio players, home theater, air conditioner, and room lighting come with remote controls that are used to select items and change status. As a result, people keep many remote controls to interact with their home devices. In addition, each control has different look and feel and functions assigned to buttons. This configuration gives the user difficulty in browsing information and finding a correct button. Sometimes the user needs to press a button repeatedly to set the volume and TV channel.

In order to address theses limitations, we developed a universal remote control that provides easy-to-use control and simple interface to control home appliances (see Fig. 1). The remote control we have developed consists of a touch screen, a force-feedback dial knob, and two buttons instead of many buttons.

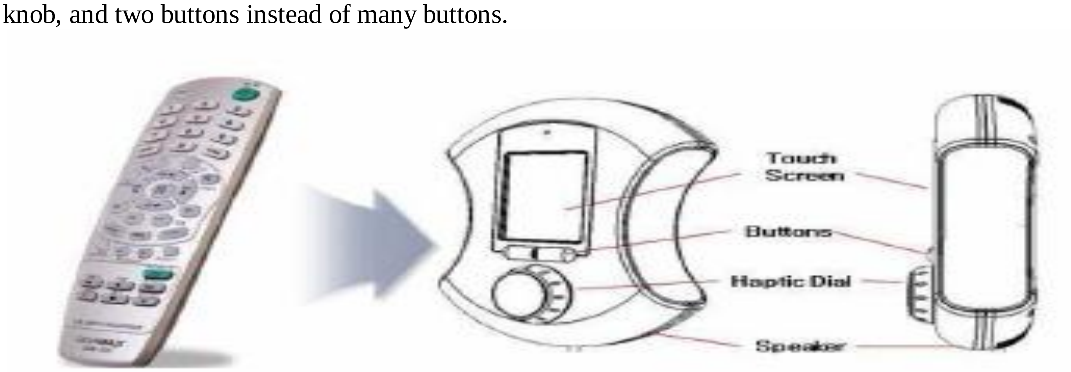


Fig. 1. Concept of the universal remote control. It consists of a LCD touch screen, two buttons, and a haptic dial.

II. PREVIOUS WORK

Recently haptic interfaces have been developed that allow users to interact with digital information via the sense of touch. Haptic technology has various customer electronics such as mobile phones, touch screen, automobiles, and games.

Over the past several years, there have been a number of studies of haptic feedback controls. Karon E. MacLean et al. introduced a variety of haptic devices and design parameters [1-3]. They considered characteristics of the touch sense and designed various tactile signals on their experimental devices. El Saddik A. suggested an identity authentication method using a haptic device [4]. He extracted behavioral features when users controlled the device and used the features to identify them.

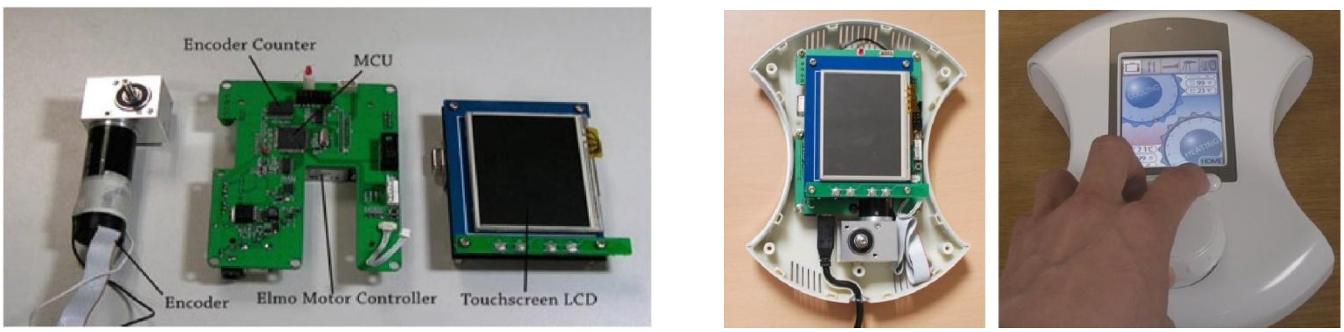
Several studies have been conducted of the 1 DOF (Degree of Freedom) dial knob. Scott S. Snibbe et al. suggested several haptic techniques for manipulating digital media based on intuitive physical metaphors [5]. Mircea Badescu et al. developed a single force feedback knob to imitate the senses of various conventional control knobs in motor vehicles [6]. Laehyun Kim et al.

used a haptic dial system for multimodal prototyping in the early phase of product development [7]. They applied the haptic technology to prototype the dial module of a washingmachine. There are several works to apply the haptic interface to games. Yuichiro Sekiguchi applied the haptic effect to a game, proposing a device that gives a user the illusion of a virtual object inside the device when shaking it using accelerators and actuators [8]. Wanjoo Park et al. proposed a brickout game using a haptic dial interface and some haptic effects for the game [9].

Recently a remote control manufacture announced a universal remote control with tactile feedback and touch screen. When the user touches the button, the remote generate simple vibration.

III. IMPLEMENTATION OF THE CONTROL

In this section, we explain in detail the hardware configuration of the haptic dial knob. A block diagram of the system is shown in Fig. 2.



(a) Motor, Control unit PCB and Touch screen module (b) Haptic remote control

Fig. 2. Implementation of the universal haptic remote control

MCU (Micro Controller Unit) computes the torque amount at a given angular position and sends the command to a DC motor via a DAC (Digital to Analog Convertor). The DC motor executes the command and generates various haptic patterns. We use a gear box of 5:1 ratio to change the angle of rotation axis. The dial knob is installed on the motor gear box, allowing the user to rotate the knob and to feel various haptic effects which are programmed along the angular position. An encoder measures the angular position with 1000 pulse per turn and an encoder counter has a 24-bits quadrature counter and 25MHz count frequency. A Touch LCD Module is used to display visual information and to allow touch input.

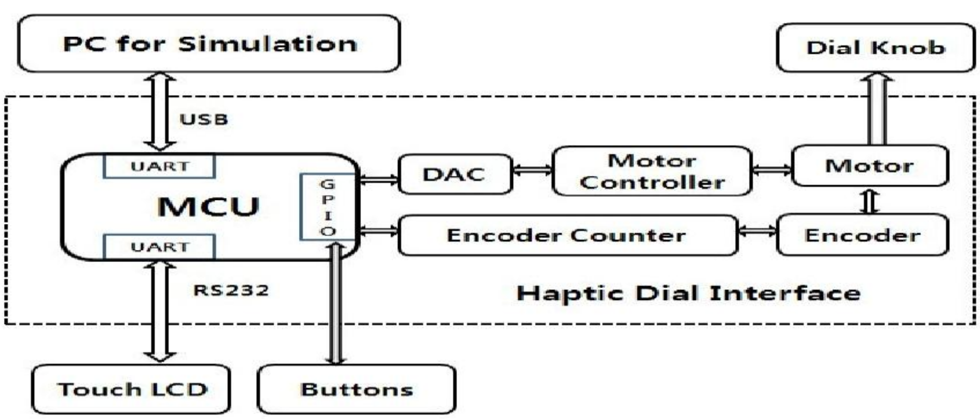


Fig. 3. System architecture of the haptic dial interface.

IV. GRAPHICAL USER INTERFACE (GUI)

GUI for the universal remote control consists of main (home) menu, TV channels, room temperature, and room lighting. The main menu has three icons that represent three sub menus to control home appliances. The user can select one of them by touching an icon. He/she can go back to the main menu by pressing the right button (we called it 'home button') anytime and select other home devices (Fig. 4(a)).

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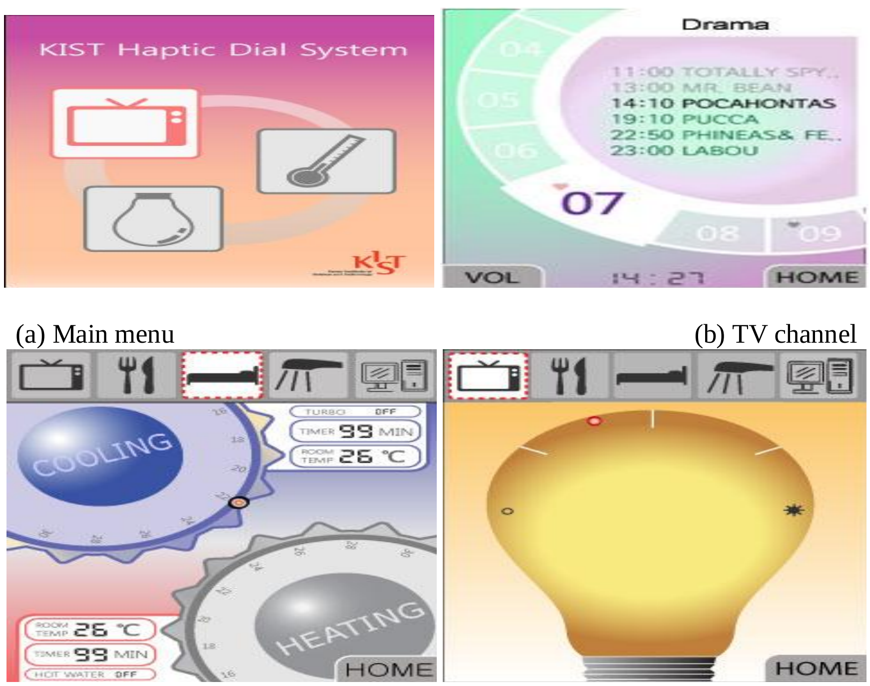
TV channel menu shows the channel list and information about current selected channel. The channel numbers are displayed on the rounded band to go well with rotational action of the dial knob. Some numbers has the heart mark that indicates popular channels or favorite channels programmed
by the user. When the user selects the channel with the heart mark, he/she feels different tactile feedback. It helps the user to find intuitively the channel that he/she may want to see (Fig. 4(b)).

In room temperature menu, the user can select cooling or heating function by touching the screen and control the room temperature by spinning the dial knob. Yellow point indicates the current temperature the user select. The user spins the dial easily in the proper temperature range. But he/she feels strong tactile feedback out of the range (Fig. 4(c)).

Room lighting menu shows a light bulb to visualize room lighting. As the user rotates the dial knob, the brightness of the bulb is changed to indicate the room lighting level. The user feels the increasing/decreasing friction when he/she spins the dial clockwise/counterclockwise. It gives very institutive interface visually and haptically (Fig. 4(d)). The red point indicates the current brightness level on the bulb.



(a) Main menu (b) TV channel

(c) Room temperature (d) Room lighting

Fig. 4. Graphical user interface for the universal remote control. Main menu (a), TV channel (b), room temperature (c) and room lighting (d)

V. HAPTIC EFFECTS

In this section, we describe how to implement various haptic effects for the universal remote control. We designed various haptic effects which are defined by adjusting torque profiles along the angular position and time. Haptic effects include detent, friction, hard stop, and a combination of these effects. These haptic effects help the user to browse and find information easily and intuitively.

A. TV channel control

In order to give a feeling to select a channel to the user, we use the detent effect. The detent effect simulates notches with different height along the angular position using sine functions. Feeling a notch confirms each channel selection. Eq.

(1) shows the detent effect which is defined by a sine function.

$$f_d(\square)\quad A_{\square}\sin(b\,\square) \qquad \text{-----------} \quad (1)$$

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where, $A_ş$ is the amplitude, *b* is the number of notch per turn, *ş* is the rotation angle of the dial knob.

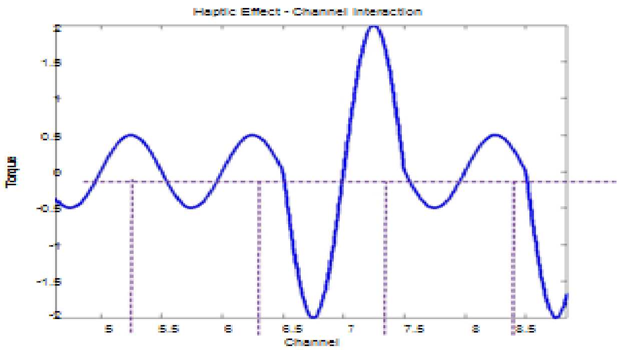

Fig. 5 Haptic profile by channel changing

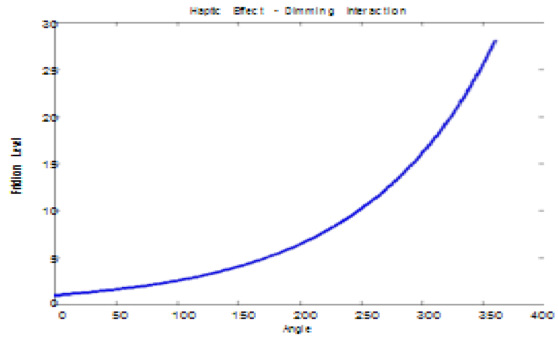

Fig. 6 Friction level by angle position

The torque profile for the detent effect is shown in Fig. 5. By modulating $A_ş$ and *b*, the amount and frequency of torque can be changed. We set $A_ş$ to a bigger value for the popular or favorite channels having a heart mark in Fig. 4(b) so that the user can identify the channels intuitively. For instance, channel 7 is a favorite channel and channel 5, 6, and 8 are non popular channels (Fig. 5).

B. Room lighting control

Friction haptic effect is used to adjust the room brightness level by rotating the dial knob. The friction effects generate resistant torque opposite to the direction of movement as a movement-based effect. This is implemented based on the friction con model [10]. The friction torque can be calculated by eq. (2).

$$
\begin{aligned}
&L_f = \exp(P_{now}(n)/S_{f1}) \\
&P_{curr\_f}(n) = P_{prev}(n-1) + (P_{now}(n) - P_{pre}(n-1)) \cdot S_{f2} \\
&P_{diff}(n) = (P_{now}(n) - P_{curr\_f}(n)) \cdot L_f \\
&P_{prev}(n) = P_{curr\_f}(n) \\
&if \quad P_{diff}(n) > T_{f\_\max} \quad then \quad T_f(n) = T_{f\_\max} \\
&elseif \quad P_{diff}(n) < T_{f\_\min} \quad then \quad T_f(n) = T_{f\_\min} \\
&else \quad T_f(n) = P_{diff}(n)
\end{aligned} \qquad (2)
$$

where *Pcurr_f* is the current position, *Pnow* is the angularposition of the dial knob, *Ppre* is the previous position, *Sf1* and *Sf2* are the scaling factors, *Pdiff* is the difference of position, *Lf*is the friction level, *Tf* is the friction torque. *Lf* (friction level) increases exponentially as the brightness level increases since the exponential increasing make much better feeling than the linear motion (Fig. 6). We designed the friction profile depending on the dial knob's movement. WhenOn the other hand, when the user spins the dial fast, he/she feels more string friction. Fig. 7 shows the profile of thefriction according to the knob movement. the dial knob is rotated slowly, the rotational friction is low.

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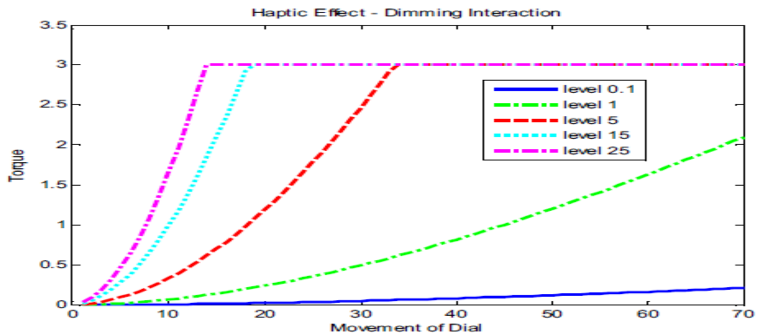

Fig. 7 Torque profile comparison of levels

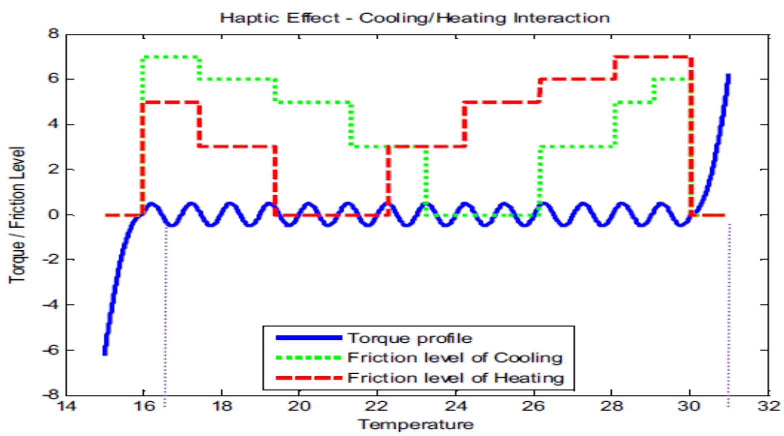

Fig. 8 Haptic profile and friction level by temperature

where, *T* is temperature, *Sb* is scaling factor, *AT* is theamplitude, *b* is the number of notch per turn, □ is the rotation angle of the dial knob.

VI. APPLY TO GAME CONTROLLER

We applied the universal remote controller to a game controllerthat gives the user haptic feedback during the game. For this, wedeveloped a new brickout game in which conventional bricks arereplaced by banana bricks, a game ball is replaced by a monkey,and a paddle is replaced by people holding up boards. In addition, a new item is added, a cloth wrapper The banana bricks work the same as general bricks and the cloth wrapper contains haptic items. The game ball bounces off the top or side of the wall depending on the collision conditions between the ball and the paddle. When the ball hits a cloth wrapper, the haptic item falls down. If the user catches the item by moving the paddle, a predefined haptic effect is felt that lasts a few seconds. This haptic feedback can make the game easier or more difficult.

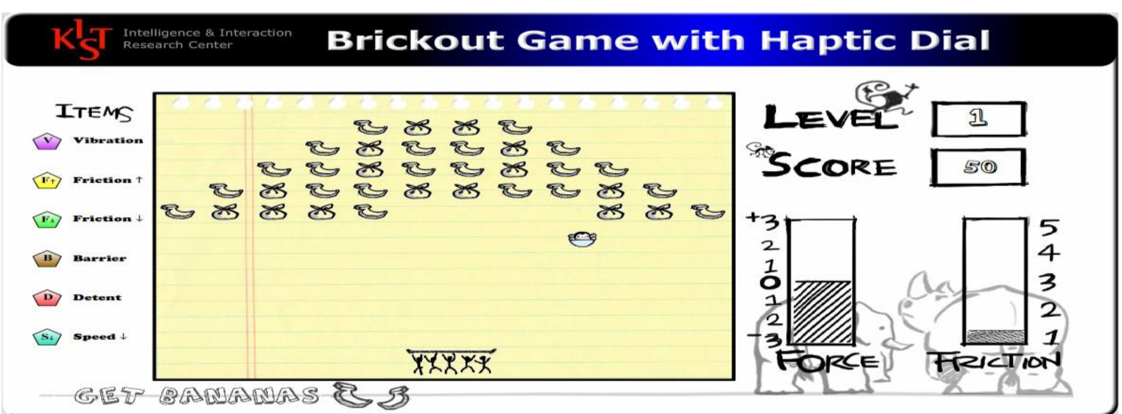

Fig. 9 Development of a new brick out game

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Fig. 10 Playing a brickout game using the universal remote control

VII. USER STUDY

We performed a user study to evaluate usability of the universal remote control.

A. Usability factors

For the user study, we followed a guideline suggested by Jinwoo Kim [11] who defined usability factors with a hierarchical structure. We choose appropriate factors to measure the usability of the universal remote control (Fig. 11).

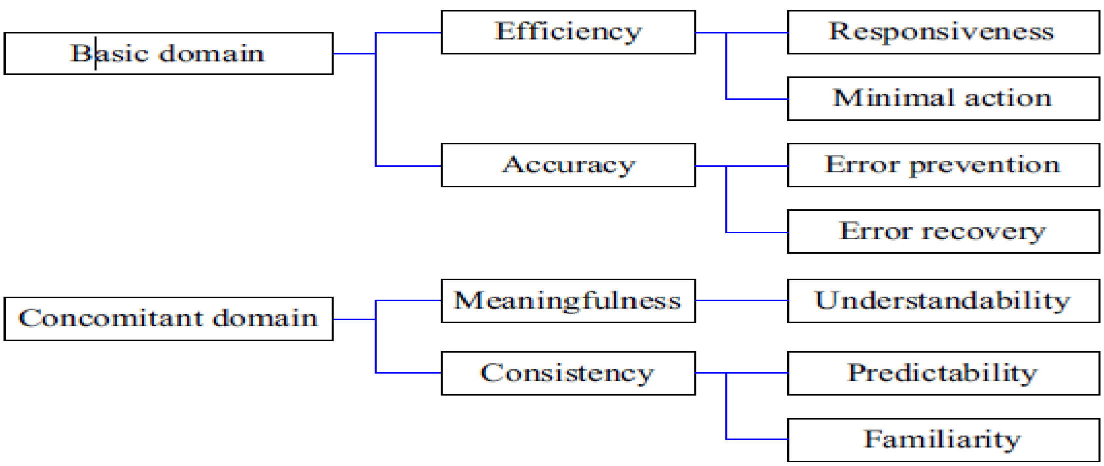

Fig. 11 Evaluation factors of usability suggested by Jinwoo Kim.

Evaluation factors in the first level consist of basic andconcomitant domains. In the second level, the basic domain has two factors; efficiency and accuracy factor. Efficiencyfactor is about how effectively users can achieve given tasks in terms of responsiveness and minimal action.Responsiveness is a factor to measure the response time and minimal action is about how simply users can deal with given tasks. Accuracy factor is about user's mistakes while using thecontrol and has error prevention and error recovery. Errorprevention is about how well the remote control prevent user'smistake and error recovery is about how easily users cancorrect the mistakes.

Similarly, the concomitant domain has meaningfulness andconsistency factors. Meaningfulness is a factor to measure how well the remote control provides information andfunctions which users want to use. Meaningfulness hasunderstandability that is about how well users can understandsystem status via given information. Consistency is to measurehow similar a function of the remote control is to otherconventional ones. Consistency has predictability and familiarity as detailed factors. Predictability is about how wellusers can predict instructions of the remote control through experience of using other similar ones. Familiarity is abouthow easily users can know instructions of a system through experience of real world.

B. Method

Subjects are 20-30's thirty people who are familiar with the conventional remote controls. Before starting the survey, we gave information about the universal remote control and allow subjects to use it freely for 5 minutes. Subjects did not knowthe task scenario and are asked to do tasks one by one usingthe universal remote control. These tasks are below:

1. Temperature control: You came back home and it is too cold, -5 °C outside. You are sitting down a sofa and control indoor temperature to 28°C.
2. TV Channel control: Now, you want to watch TV. The defaultchannel is number 2 and it is boring to you so you change the TV channel to your favorite channel, number 11.
3. Temperature control: you feel it is too warm. You controlindoor temperature to proper temperature in winter season,24°C.
4. TV Channel control: Now, TV shows some advertises. Youchange the TV channel to number 17 for searching anotherprogram.

After completing the tasks, subjects were asked to answer a questionnaire. The questionnaire for the user study is divided into three sections such as general control (touch screen), TVchannel control and temperature control. The light control section is excluded because it is not popular way to control bya remote control.There are five questions excepting sponsiveness andrecovery factor in general section. For channel andtemperature section, there are eleven and ten questions eachsection with seven factors. Questions on the questionnaire were 7-point (-3 to 3) Likert scales.

C. Result

Fig. 12 shows results for each factor. For 'Efficiency'dimension, both of 'Responsiveness' and 'Minimal Action'got the high scores (2.50 and 2.08 respectively). It means thatthe user can use the universal remote control effectively. Thesubjects said that the haptic dial knob is very intuitiveinterface to control TV channel and temperature. The touchscreen also provides easy-to-use interface to select menus.For 'Accuracy' factor, both of 'Error prevention' and 'Errorrecovery' got the medium scores. 'Error prevention' factor gotmedium score (1.39). The score for 'Error prevention' ofGeneral (main screen) was not high (0.86) because if it is notcorrect position on touch screen, the system operates anotherprogram. In the case of 'Error Recovery' factor, temperaturecontrol got high score (2.27). As the results of interview,subjects recognized it is useful that friction is increased asdeviate degree from proper temperature.

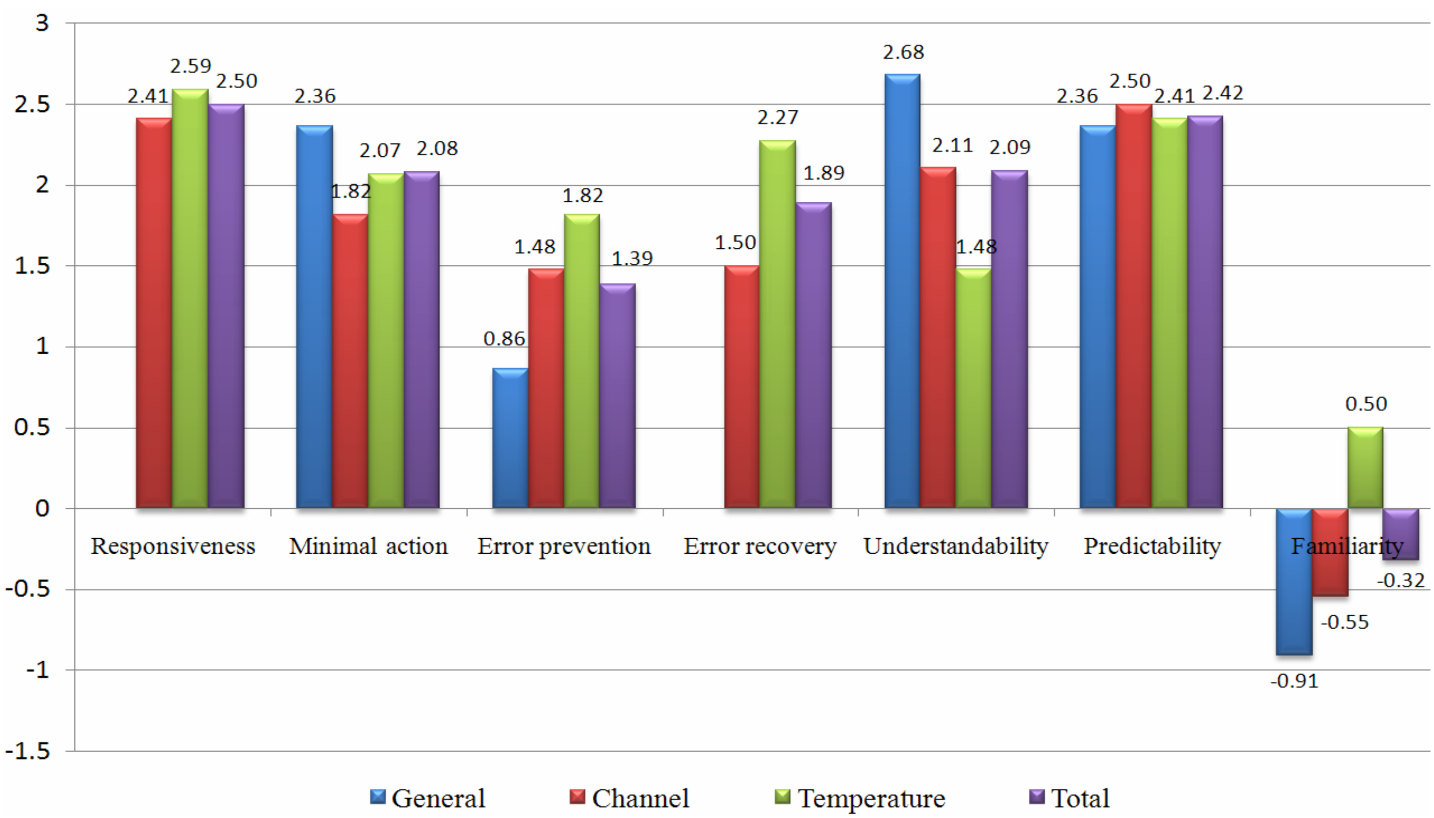

Fig. 12 The results of user-study

For 'Meaningfulness' factor, 'Understandability' got highscore (2.09) and especially for the general section got the highest score (2.68) because touch screen display showsvarious information according to context such as current temperature and channel information.In case of 'Consistency' factor, 'Predictability' got highscore (2.42). It means the universal remote control has very simple and stable interface. However 'Familiarity' has very low score (-0.32) because our universal remote control has a dial knob with haptic feedback and a touch screen unlike conventional remote controls.

VIII. CONCLUSION

Today people need to keep several remote controls to control home appliances in their living room. Universal remote control allows people to control multiple devices using a single remote control. However conventional universal remote controls still have problems. Many buttons make the user spend time to browse and find the right one. In many case,people need to press a button several times, for instance volume control and TV channel selection. In addition, the user needs to read and remember the manual before he/she use it.

In this paper, we introduce a new universal remote controlto address these limitations. It has a simple interface which consists of a touch screen, two buttons, and a dial knob with haptic feedback. Touch screen can display various information and be used an input device to select home device the user want to control. Two buttons is used for the power on/off and returning to the home menu. Haptic dial knob provides a very intuitive input and output interface. The user can change the status by rotating the dial knob and at the same time, he/she receives tactile feedbacks depending on the situation.

Our universal remote control allows the user to control TV channel, room temperature, and room light brightness. In addition, we applied the device to a game controller for a brickout game. It makes the game more fun and more immersive. The result of a user study to evaluate the usability shows that our universal remote control is very efficient and intuitive device to control home appliances.

In the future we will design new haptic effects to control other devices and make the universal remote control smaller and lighter for better usability.

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