A Study for Usability Risk Level in Physical User Interface of Mobile Phone

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Abstract. The purpose of this study is to develop a framework of quantitative evaluation of PUI risk level to ensure the usability in designing mobile devices. Three PUI factors—key type, use scene and device form—were selected as the main criteria for PUI risk level. They are defined as Key Manipulation Value (KMV), Function Manipulation Value (FMV) and Handling Value (HV), considering the requirements. In short, this study provides a framework of quantitative evaluation with the requirements of the three PUI factors, and analyzes risk level by KMV, FMV and HV. This result can be utilized as a criterion for usability at the design phase. In addition, evaluation with this framework at the early design phase helps to anticipate the problems, so the opportunity to solve the problem can be offered in advance.

Keywords: Mobile Phone, Physical User Interface, Risk Level.

1 Introduction

These days, many electronic products are rapidly improved by development of digital and telecommunication technologies. As various functions are added in digital products, product's UI, exterior design, application and usability are affected by these additional changes. Especially, mobile devices are no longer only a device for calling and sending SMS. New functions such as camera, game, DMB, GPS and wireless internet have been established as core components by development of advanced software and hardware technology. This multimedia device has become feasible through digital convergence. Also it became a core-device to satisfy users' various requirements in many fields such as entertainment, business and information [4]. However, as various functions are added into one small device, complexity of the device is causing inefficiency in device control [7]. Therefore UI design that can support user satisfaction and ease of use is getting important.

In general, UI is classified with Graphic User Interface (GUI) and Physical User Interface (PUI). PUI is the term that includes practical and physical characteristics which is related to device's exteriors like buttons, switches and levers to manipulate the device. This must be concerned in early design process and is highly related to context of GUI, which executes applications through display and gives a feedback

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from its execution [2]. Desktop users devote all of their visual resources to the application which they are interacting. In contrast users of mobile devices, are typically in motion while they are using their device, can not devote their all resources to interact with mobile application. Moreover, the mobile devices are getting smaller and more multi-functional so the form types are expanded from basic form type, bar type, folder type and slide type to advanced and mixed type, swing and swivel type. This change causes difficulties in use due to limited screen real estate and limitation in design of physical buttons [1]. Thus, multi-functional and minimized mobile device has more problems than other digital devices, which leaves an important challenge to overcome the limitation of efficient control for using many functions of devices. Mobile device is a unique type of digital convergence appliance in that PUI and GUI are combined. Therefore, it must be designed with advanced paradigm as preceding ergonomics about hand-tools [6].

In this paper, ease of use is evaluated in the aspect of PUI of calling, SMS, camera, MP3 and DMB using mobile device that is affected by mobile device's physical components(device type, button type and button position). Three PUI evaluation factors are selected: key-type, use-scene, form-factor. Key-type evaluates the degree of efficiency about performing task, use-scene evaluates controllability due to button region and button type, and form-factor evaluates the degree of interruption among key types. The three PUI evaluation values are defined as Key Manipulation Value (KMV), Function Manipulation Value (FMV), Handling Value (HV), respectively. Each of three evaluation values generated mobile device's PUI risk level by estimating requirements related to PUI. Also, the alternatives, which can solve the problem of PUI, are made by analyzing the reasons of high risk level. As a result, mobile device's risk level can be evaluated by three defined PUI evaluation values - KMV, FMV and HV. By these, PUI evaluation framework is generated, which can find the predictable problems of ease of use and manage the problems in early design step.

2 Literature Review

Previous researches were examined to extract requirements about key-type, use-scene, and form-factor.

In most of previous studies about requirements of Key-type, improving user performance in each task was the main issue. Nielsen studied supporting visual and tactile feedback to improve tool's controllability[5]. Also, the necessity of error prevention which reduces errors occurred from user's mistakes is mentioned. These are main requirements for hand tool device. Shneiderman researched to improve menu navigation for structural and nonstructural information searching by measuring frequency of button usage, accessibility for manipulation, user satisfaction [12]. This research is about most efficient button which can support user in discrete and continuous tasks. And the result can be applied to the navigation button for menu navigation. Furthermore, the Kasper divided difference of multidimensional control and unidimensional control, and different applicable range of various control types related to discrete control or continuous control were analyzed in this paper [9].

About interface design of mobile device's keypad, efficient text input and control method were studied, and intuitive and efficient guideline for key arrangement was researched. A new advanced input method was proposed with consideration of balancing input efficiency, ergonomics, usability and cost [11]. Also text input using mobile device is emphasized and a research about comparison and evaluation by calculated input time by Fitt's law was done by Silverberg [13]. Even though it needs little force to manipulate device, user can feel fatigue by finger angle in short time. For that reason, maximum muscular strength which is changed by finger angle during key control with grasping device is also researched [3]. In this research, interface design, which is considered button controllability, accuracy and interference, is required.

Lastly, there were many researches about finger's muscular strength that is related to hand grip and button control design of electronic product in ergonomics' view. This paper focused not only on tool grip design but also on optimizing the best knob shape and size, grip force and grip type using anatomic structure of hand [8]. Miniaturization of mobile device will bring difficulty at the input method. For that reason, Nambu Hirotaka proposed that users need to grip different part of device when using the right bottom part of mobile device [10]. When user tries to input character continuously, the grip-stability with some friction can provide comfort to users; additional research about a bottom part of mobile device's grip is performed.

3 Risk Level Evaluation Methodology

Evaluation of mobile device's risk level consists of 4 steps. In the first step, mobile device's features of existing mobile phones are analyzed. The form of device and motion of each form are analyzed as well. Also types of each key and main keys for controlling calling, SMS, camera. MP3 and DMB were investigated. In second step, 3 PUI evaluation factors(key-type, use-scene and form-factor) requirement are collected through previous researches and literature research to estimate the requirement's weight. In third step, the values of KMV, FMV and HV are defined to calculate the risk level quantitatively. Finally, the last step evaluated PUI risk level of mobile device according to evaluation framework of risk level (Fig. 1).

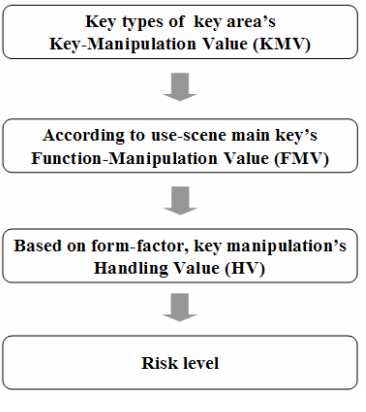

Fig. 1. Framework of PUI risk level

3.1 Feature Analysis of Mobile Devices

Physical movements of different device types are analyzed for evaluating PUI risk level. 133 products (Domestic product: 101, Foreign product: 32) were analyzed. Mobile devices are divided into 4 kinds of form-type(bar, folder, slider and swing). And each different form-types of devices had 13 physical transformations (Table 1). Bar-type consist of normal bar-type and mixed bar-type. Normal bar-type is bar-type without transformation. And mixed bar-types are combined with swing or swivel type. Folder-type consists of normal type (up type) and abnormal type (left-right, up-swing and up-swivel type). Slide-type is divided into up, down and up-down type. And there are mixed slide-types which are combined with up type and swing type or swivel type. Normal swing-type is also founded. We defined two positions of mobile devices. The position without transformation is defined as 'base position' and the position with ion is defined as 'home position'.

Table 1. Form of mobile devices

Form-type	Form-factor(Movement)
Bar	Bar
	Bar + Swing
	Bar + Swivel
Folder	Up
	Right and Left
	Up + Swing
	Up + Swivel
Slider	Up
	Up + Down
	Down
	Up + Swing
	Up + Swivel
Swing	

Mobile device is divided into navigation area, function area, numeric area and side area, and key-type of each area were investigated (Table 2). And dorm key, touch key, jog-disk, jog-stick and wheel are used in each key-area of mobile device.

Table 2. Key-type in each key-area

Key-area	Key-type
Navigation	Dorm key, Touch key, Jog-disk, Jog-stick, Wheel
Function	Dorm key, Touch key, Jog-disk, Jog-stick
Numeric	Dorm key, Touch key, Wheel
Side	Dorm key, Touch key, Jog-disk, Jog-stick, Wheel

Generally in mobile device, there are various functions. However in this research 5 main functions(calling, SMS, camera, MP3 and DMB) which have high usage

frequency were selected to be evaluated. Also main-key in each key-area was selected to analyze the key-area which is needed to control each functions (Table 3).

Table 3. Main-key and key-area in each function

Function	Main-key	Key-area
Calling	Numeric key	Numeric
	Calling, clear, end key	Function
	Volume control key	Side
Short Message Service (SMS)	Numeric key	Numeric
	Mode switch key	Function
	Clear, confirmation key	Function
	Specific letter key	Navigation
Camera	Shutter key	Function
		Side
	Zoom key	Navigation
		Side
	Brightness control key	Navigation
		Side
MP3	Play, Stop key	Function
	Music search key	Navigation
	Volume control key	Navigation
		Side
DMB	Channel switch key	Navigation
		Numeric
	Volume control key	Navigation
		Side

As a result of investigation and analysis, classified form-type of mobile device, key-type in each key-area and main-keys in each function were selected as evaluation components.

3.2 Requirement Collecting and Weight Assessment

Requirements asked in PUI factors (review, key-type, use-scene and form-factor) are collected through literature review. And by selection process, 16 requirements are selected; 8 of key-type, 6 of use-scene and 2 of form-factor (Table 4).

Requirement's weight of Key-type was estimated by considering main goal and task of each key-area. About use-scene, requirement's weight was estimated by considering key controllability, performance of key control and interference in key control. Also requirement's weight of Form-factor was estimated by considering interference and stability between form of mobile device and motion of key-type.

The weights of each requirement were verified by HCI experts and mobile device designers' discussion.

Table 4. Requirement and definition

PUI factors	Requirement		Definition
Key-type	Feedback		Provide tactile feedback using control keys or not
	Quick navigation		Degree of providing shortcut to navigate in menu which is consist of many list
	Detail control		Degree of providing detail control of small numeric unit (ex: volume, zoom)
	Eye-tracking		Degree of providing key manipulating without eye-tracking
	Multidimensional control		Degree of providing multidimensional control in 2 levels
	Error		Degree of providing accurate key manipulation
	Thumb range		Degree of providing natural key manipulation in Thumb range
	Task performance		Degree of performing task
Use-scene	Thumb range according to main used key	Stability	Degree of grip-stability based on key manipulation and hand position for using function
		Accuracy	Degree of accuracy of key manipulation by thumbs' movement
		Controllability	Degree of controllability of key manipulation for using functions
	Interference		Degree of interference between manipulated key and other keys
	Cognitive		Degree of cognitive key manipulation
	Performance		Degree of performing key manipulation task
Form-factor	Stability		Degree of grip-stability during key manipulation in each form-factor
	Conflict		Degree of conflict between key manipulation and form-factor's movement

3.3 Risk Level Definition

About PUI risk level which can evaluate PUI factors quantitatively was defined. Three values were defined. KMV in key-type is related to controllability and usability for performing task efficiently is defined. FMV of use-scene is related to controllability and usability of key manipulation for using functions. And about Form-factor, HV is related to controllability and usability of those is changed by transformation of mobile device's form. Table 5 shows the value which represents the degree of control efficiency for evaluating PUI risk level.

Table 5. Control efficiency value

Value	Requirement	Definition
KMV (Key Manipulation Value)	Key- type	Degree of control efficiency of each key-type during performing task
FMV (Function Manipulation Value)	Use-scene (Function)	Degree of control efficiency of each key-type during performing function
HV (Handling Value)	Form-factor	Degree of control efficiency of each key-type during performing function in each position

3.4 Risk Level Evaluation

PUI risk level is evaluated in 3 steps. Figure 2 shows evaluation procedure of PUI risk level. In first step, KMV is generated by evaluation of the degree of requirement's satisfaction in 5 investigated mobile devices' key-types. In second step, FMV is generated by evaluation of the degree of requirement's satisfaction in use-scene using KMV which is generated in first step. Similarly, HV is generated by evaluation of the degree of requirement's satisfaction in each form-factor using FMV. Lastly 1 minus HV value is risk level of mobile device.

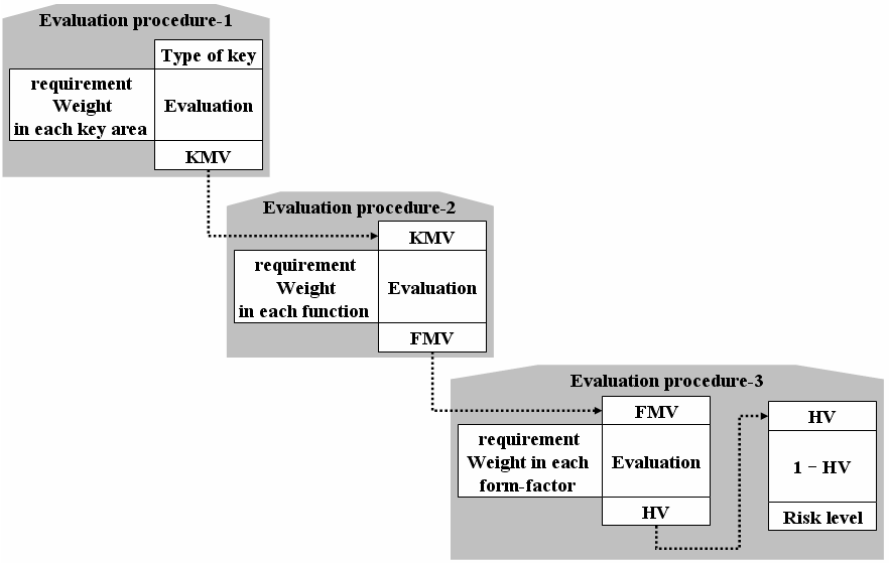

Fig. 2. Evaluation procedure of PUI risk level

Figure 3 shows the method that calculates KMV, FMV, and HV. Using this measurement method, for the last, PUI risk level was calculated.

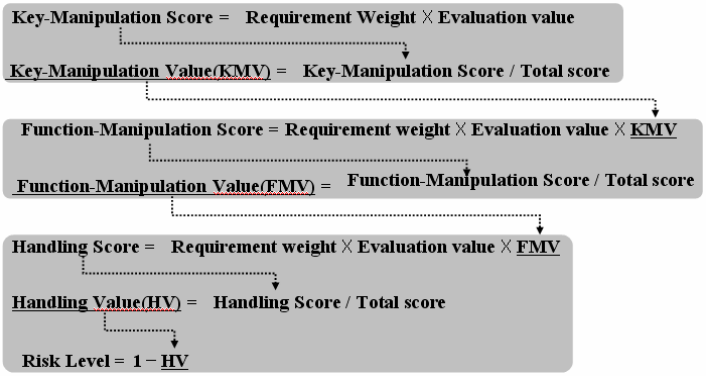

Fig. 3. Measurement method of KMV, FMV, HV

4 Conclusion and Discussion

The result of PUI risk level is produced by mobile device evaluation method of this paper. For example, figure 4 shows the results of risk level of 11 bar-type mobile devices.

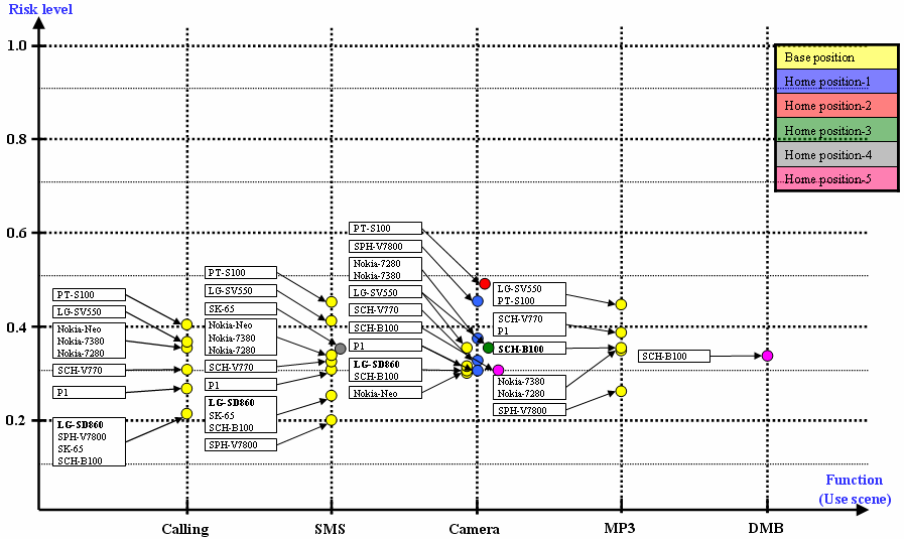

Fig. 4. PUI risk level of bar-type mobile device

In this paper, mobile device's requirements of PUI factors; key-type, use-scene and form-factor are extracted. And we developed risk level evaluation framework for mobile device's PUI design using quantitative value; KMV, FMV and HV. Using this framework, in early design step, designers can evaluate PUI risk level quantitatively.

In consequence, the framework provides quantitative result based on organized method for mobile device's PUI factors. Also as problems of PUI in early mobile device concept were predictive, designer can get an oppotunity to solve the problems easily. However, we only focused on PUI factors without GUI factors in this research so that the evaluation framework can't deal with whole part of mobile device. Therefore further work that includes menu structure and visual component(GUI factors) is needed.

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