
Extended KLM for Mobile Phone Interaction: A User Study Result

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Abstract

Facing with the fast development of mobile phones, the designers need to evaluate user performance for early responding to the potential interaction problems. Previous studies show that the original Keystroke-Level Model (KLM) has been successfully used in conventional computer-based interaction design. However, with the emphasizing of the next-generation design and new interactions in mobile phones, the existing KLM cannot fulfill all range of mobile-based tasks. This research aims to present discussions on extending KLM for mobile phone interaction. In addition to the basic operators in conventional KLM, another fourteen new operators and a new concept – operator block were proposed. This extended KLM will help designers to reach a full-fledged user performance model for mobile phone interaction.

Keywords

Keystroke-level Model (KLM), mobile phone interaction, user study

ACM Classification Keywords

H.1.2. User/Machine Systems: Human factors, Human information processing. H5.m. Information interfaces and presentation (e.g., HCI):Miscellaneous.

General Terms

Human Factors, Theory

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Introduction

Technology makes sense only when it serves human best. When complicated functions are developed for mobile applications, the problems of presenting applications in small screen and interacting with users conveniently become great challenges for mobile device designers.

Experience has shown the importance of evaluation in early stage of system design and development procedure. The early evaluation can help designers to obtain contextual framework and user performance of a new design. With this information, designers can quickly respond to the potential problems. In traditional design process, referring to handbooks can be useful in early stage, but the limitations of few quantitative directions make it not a perfect solution. Another typical technology is high fidelity prototyping, together with experimentation, which are time consuming and expensive [9]. Researchers need a fast evaluation method integrated with the knowledge of human factors, ergonomics guideline and system-level predictive evaluation data. Human performance models are a wise choice to meet these requirements, due to its high reliability, low cost and less time consumption.

In order to address the next-generation interaction design and cope with the fast development of new interactions on mobile phones, this research presents discussions on human performance models based on mobile phone interaction. The study focuses on extending the KLM which has been successfully used in conventional computer-based tasks and shown useful in mobile phone interaction design. A user study was performed to obtain the set of new operators. By using

extended KLM, designers can obtain early design evaluations.

Literature Review

Since the publication of the Psychology of Human-Computer Interaction, Goals, Operators, Methods, and Selection rules (GOMS) has become a standard of analytical technique in the study of HCI. A well-known and widely used variant in GOMS family is the KLM [2]. The KLM is acknowledged as an accurate, quantitative, and prior prediction method for early-stage analysis of interaction design. As the simplest form of GOMS, the KLM only consist of methods and operators, and its scope is restricted to expert users, error-free tasks, and specific methods without selection rules.

For the past decade, research of KLM in mobile context began with studies on mobile text entry methods, for example, Silfverberg, MacKenzie and Korhonen presented a model to predict expert text entry rates for several input methods on a 12-key mobile phone keypad [13]. Dunlop and Crossan declaimed that the execution time parameters of original operators in KLM were no longer precise for mobile devices [4]. How and Kan defined 13 operators that more directly map onto the phone keyboard interface according to different input methods [6]. There were also studies working on special language such as Myung's research in Korean messages text entry [11]. However, in China, there is no native researcher who has studied Chinese text-entry in mobile interaction with the KLM, and only the Singaporean researchers [6] made some relative conclusions on messages text entry in mixed English and Chinese.

In recent years, with the emphasizing of the next-generation interaction design and coping with new interactions in mobile phones, researchers began to shift their attention to new interactions, for example menu interaction, tag interactions, mobile camera interaction, etc. Amant, Horton and Ritter studied user performance on 5 simple tasks of menu traversal on a cell phone [1]. The model of GOMS showed very good predictions of behavior compared with Fitts' Law. Luo and John applied the KLM to predict task execution on handheld devices [10]. Their work was the first validation of KLM on handheld devices. After that, other researchers continued to use KLM to predict different interacting systems. For example, the study predicting the visual demands of in-vehicle information systems by Pettitt, Burnett and Stevens [12] and the research targeted at advanced interaction with mobile phones by Holleis, et al. [5]. Most recently, John and Suzuki reported a study which expands the scope of predictive modeling to the mobile phone domain with pretty good preliminary results [7].

In summary, the KLM technique is device-dependent, and there is a significant lack of the norms for mobile applications. In the past few years, the types of existing mobile interactions have increased a lot. In order to address the next-generation interaction, simply applying the conventional KLM from computer to mobile device is improper because there is a large gap between these two kinds of devices. Although in some studies the KLM was applied to mobile devices without any change, these studies were not able to consider the overall range of mobile-based methods and operators, and that is why the extended KLM for mobile phone interaction should be studied.

User Study

The objective of user study is to generate new operators for mobile phone interaction. The new operators combined with the operators proposed in previous studies will formulate the basic components of extended KLM. The extended KLM will keep the definition of unit task, which is a small cognitive manageable, quasi-independent task [2,3]. The unit task should include two time sections: acquisition of the task and execution of the task. The mobile interaction should occur during the execution of the task.

GPS application was selected as a representative advanced application to explore and generate new operators. GPS application is one of the most desirable functions in mobile products, and the dynamic contexts of it embody almost all the technical restrictions of mobile devices. According to a survey by the Pew Internet and American Life Project in March, 2006, the ability to look up maps (47% of all responders) became the most desirable function for modern mobile devices. Because GPS applications are essentially advanced mobile applications, the users should be the experienced on mobile phone interaction, which ensure the experts restriction of KLM.

Systems

Two GPS navigation systems were studied in this study: Route 66 and Careland. Route 66 is acknowledged to be the most popular mobile navigation software, while Careland is the most famous one developed in China. Two mobile phones: Nokia 6110n and BenQ P51 were selected to install Route 66 and Careland separately. The two selected mobile phones contain three typical input methods: 12-button-keypad, QWERTY, and touch screen.

Participants

Three participants (2 males and 1 female) who have good understandings about KLM were selected in the experiment. Besides, all the participants are proficient at mobile phone interactions and GPS application. They have at least four years of mobile phone use experience, more than one year of smart phone use experience, and three to six months experience on navigation system.

Tasks

The participants were asked to walk through a typical mobile navigation task: route planning from an origin to a destination. During the task, participants were asked to record their own keystroke-level action sequence in a spreadsheet template. Their action sequences were further analyzed by researchers to generate operators.

To finish the task, participants should use four different text entry methods in BenQ P51 and one text entry method in Nokia 6110n. The four text entry methods in BenQ P51 are: (a) the dynamic searching with initial of pinyin, (b) the soft keyboard tapped by a stylus, (c) the handwriting input, and (d) regular QWERTY keyboard input. For Nokia 6110n, either stroke or Pinyin could be used to accomplish the task.

New Operators

The results generate fourteen new keystroke-level operators for mobile phone interaction, which includes five mental operators and nine physical operators. Table 1 gives the name of new operators and their descriptions.

	Operator	Description
Mental Operator	MI	Mentally initialing a task
	MD	Mentally deciding or choosing
	MR	Mentally retrieving
	MF	Mentally finding
	MV	Mentally verifying
Physical operator	FK/SK	Flipping or slipping to induce keyboard of mobile devices
	T	Tapping with stylus
	HS	Homing stylus to somewhere
	HF	Homing finger to somewhere
	PS	Picking up stylus or putting it back
	R	Rotating 90 degrees to use functions such as camera, movies, browsing pictures, etc.
	CK	Continuously holding a key down
	KS	Pressing a key on the side
	P/UP	Plugging and unplugging other devices

Table 1. New Operators for extended KLM

Operator Blocks

When a user wants to tap an icon on the screen, he or she should first mentally find the icon on the screen. In the cognitive architecture, the visual processor focuses on the icon only and all the appearance properties of the icon are filled in the object store of the working memory [8]. Then, the user's manual motor processor should command the hand to home the stylus to the location of the icon and to tap it. The entire process involves three operators: MF, HS and T.

We collect all these kinds of consistent operator sequences and name it as Operator Block. Operator Block (OB) is a new concept imported to the extended KLM, which is defined as the sequence of operators that can be used with high repeatability by analyst of the extended KLM. All of the OBs obtained from user study are listed in Table 2.

OB	Description
OB-TV (HS, T, MV)	Tapping a key with stylus and verifying the input
OB-FT (MF, HS, T)	Finding an object on the screen and tapping it with stylus
OB-DV (HS, D, MV)	Drawing a line with stylus and verifying the input
OB-KV (HF, K, MV)	Pressing a key in the keyboard and verifying the input
OB-FK (MF, HS, K)	Finding an object on the screen and pressing the corresponding button
OB-nKV (HF, K*n, MV)	Pressing the same key for n times and verify the input

Table 2. Operator blocks for extended KLM

The contributions of OB lie in three aspects. First, it can help designers to reach a full-fledged KLM. Second, it is permitted that for simplification of the model analyst. Third, OB defines the norms to designers. Take OB-FT for example, the user mentally finds the icon and taps it, thus the user does not need to verify the tapping.

Unchanged Operators

The extended KLM still keeps four previous proposed operators: D (draw a line) [2], K (press a key or button on the keyboard) [2], G (hold a gesture for a certain application) [5], and HD (home the mobile device from somewhere to somewhere) [5].

Neglected Operators

Several previous proposed operators will not be adopted in this research. Each neglected operator has been considered carefully.

$W(t)$ or $R(t)$ [2] are neglected because the response of t can be overcome by the modern technology. Holleis, et al. defined several new operators [5]. Some of these operators are very useful, and we cite them directly in this research. However, there are also some operators that will be neglected here. First, the Smacro (attention shift between mobile device and real world) may be a mistakenly defined operator, because its definition suggests that it should be the acquisition of a unit task, which is supposed to be not involved in the execution of a unit task in original KLM. Second, the operator I (initial action) should also be the acquisition time in a rigorous KLM analysis. Third, the X (distraction from their main task) is supposed to be not a constitute part of the execution of a unit task, because any alternative interaction design would face the same fact that distraction may happen at any time and the judgment of which one is better should not be affected by this operator. Fourth, the Smicro (attention shift between different zones of mobile device) is also neglected here, because essentially it is a mental operator, and the similar operator in the extended KLM should be MF. Fifth, the A (action) is a general operator of a certain complex action with mobile interaction. From the examples in [5], it is clear that the operator A exists because the model essentially lacks of operators. But in the extended KLM, so far, the types of operators are enough for known practical application. The last operator that will be neglected is F (any movement of finger), which is too fine-grained and not at the keystroke-level.

Conclusions and Future Work

In the present work, we attempted to extend the original KLM for mobile phone interaction. The fast development of new interactions in the mobile context makes the study of predicting user performance in the early stage of development important. The extended KLM can be used to help designers to reach a full-fledged user performance model for mobile phone interaction.

In the future study, we plan to further conduct experiments with additional users and tasks to improve the developed set of operators. Furthermore, we plan to empirically measure the time specification of proposed operators and validate the results. Combined with the time estimation for each operator, the user performance can be obtained so that designers can quickly respond to potential problems in the early stage of the design.

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References

- [1] Amant, R. S., Horton, T. E., and Ritter, F. E. Model-based evaluation of cell phone menu interaction. In *Proc. CHI 2004*, ACM Press (2004), 343-350.
- [2] Card, S. K., Moran, T. P., and Newell, A. The keystroke-level model for user performance time with interactive systems. *Communications of the ACM*, 23, 7 (1980), 396-410.
- [3] Card, S. K., Moran, T. P., and Newell, A. Computer text-editing: an information-processing analysis of a routine cognitive skill. Human-computer interaction: a multidisciplinary approach (pp. 219-240): Morgan Kaufmann Publishers Inc, 1987.
- [4] Dunlop, M., and Crossan, A. (2000). Predictive text entry methods for mobile phones. *Personal and Ubiquitous Computing*, 4, 2 (2000), 134-143.
- [5] Holleis, P., Otto, F., Hußmann, H., and Schmidt, A. Keystroke-level model for advanced mobile phone Interaction. In *Proc. CHI 2007*, ACM Press (2007), 1505-1514.
- [6] How, Y., and Kan, M.-Y. Optimizing predictive text entry for short message service on mobile phones. In *Proc. HCII 2005*.
- [7] John, B.E., and Suzuki, S. Toward Cognitive Modeling for Predicting Usability. In *Proc. HCII 2009*.
- [8] Kieras, D. E., and Meyer, D. E. An overview of the EPIC architecture for cognition and performance with application to human-computer interaction. *Human-Computer Interaction*, 12, 4 (1997), 391-438.
- [9] Laughery, K. R., Jr, C. L., and Archer, S. Modeling Human Performance in Complex Systems. In G. Salvendy (Ed.), *Handbook of Human Factors and Ergonomics* (3rd ed., pp. 967-996), 2006.
- [10] Luo, L., and John, B. E. Predicting task execution time on handheld devices using the keystroke-level model. In *Proc. CHI 2005*, ACM Press (2005), 1605-1608.
- [11] Myung, R. Keystroke-level analysis of Korean text entry methods on mobile phones. *International Journal of Human-Computer Studies*, 60, 5-6 (2004), 545-563.
- [12] Pettitt, M., Burnett, G., and Stevens, A. (2007). An Extended Keystroke Level Model (KLM) for Predicting the Visual Demand of In-Vehicle Information Systems. In *Proc. CHI 2007*, ACM Press (2007), 1515-1524.
- [13] Silfverberg, M., Mackenzie, I. S., and Korhonen, P. Predicting text entry speed on mobile phones. In *Proc. CHI 2000*, ACM Press (2000), 9-16.