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# Using HCA and TOPSIS approaches in personal digital assistant menu–icon interface design

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ABSTRACT

Mobile electronic products have recently become very popular because of their portable convenience and versatile functions. The personal digital assistant (PDA) can even access the Internet. However, there is still plenty of room for improvement in the PDA interface. This research proposes a systematic approach to analyze, generate and evaluate a PDA integrated menu–icon interface design for the DigitHub Company based on customer requirements.

Hierarchical clustering analysis (HCA) is incorporated with the analytic hierarchy process (AHP) to identify and categorize functional PDA menus and their corresponding icons. We evaluate the importance of each of the different functional menus and categories. We generate five PDA menu–icon interface design alternatives that meet the proposed design guidelines, and we evaluate each for their respective feasibilities. The technique for order preference by similarity to ideal solution (TOPSIS) method is applied to measure the overall operating performance of the five PDA menu–icon interface design alternatives. The evaluation results show that the preferred design is option $PDA_5$, a hierarchical and separated menu–icon layout style that features a two-layer menu structure.

We expect that the proposed development procedure for the generation and evaluation of PDA menu–icon design alternatives based on customer requirements will be of interest to interface designers who wish to focus on mobile products.

*Relevance to industry:* This paper proposes an integrated procedure for designing PDA menu–icon interfaces. Our methodology should help in the creation and optimization of screen layouts for mobile phones, global positioning system (GPS) navigation devices, digital cameras and related screen interfaces.



## 1. Introduction

Given recent advances in mobile technology, the handheld personal digital assistant (PDA) has become very popular owing to its small size, high portability and personal information management and communication capabilities. Most PDAs feature a five-inch diagonal screen, stylus, and detachable or virtual keyboard. They can execute a limited set of tasks and applications. Hayhoe (2001) noted that most PDA screens feature a low resolution, low color depth, and unsatisfactory brightness with weak contrast. At present, leading PDA operating systems include Palm OS, Windows CE, Epoc and Linux. Like desktop or laptop computers, the aforementioned operating systems allow an interface designer to use components such as windows, icons, menus and pointers (WIMP) to design user-facing software. In addition, most PDAs typically feature graphical user interfaces (GUIs) that allow a user to directly manipulate icons and other graphical symbols on a screen (Stramler, 1993). The ubiquity of high-speed Integrated Services Digital Networks (ISDN) and wireless modem services can allow PDAs to access information from anywhere and at any time (Gessler and Kotulla, 1995). PDA menus are categorized as follows: hierarchical and scrolling menu interfaces with multiple layered menus (Wang et al., 2004). A hierarchical menu focuses on the function-menu structure and the associations among functional icons. The scrolling menu is similar to a menu list, in the sense that a linear concept is used to search for the desired function icon. The user can interact with a PDA by tapping, tapping and holding, or dragging a stylus to manipulate objects and menus directly on the screen.

Recently, designers encountered usability and psychological overload challenges in creating PDA software due to the limitations of screen menu interface frameworks. Kiger (1984) found that an individual's operating time is proportional to the menu selection

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depth. Snowberry et al. (1985) suggested that increasing the number of menu layers leads to mental overload and loss of direction, lengthening search time and diminishing the advantages of hierarchical menus. Dillon et al. (1990) also argued that if the number of menu–icons exceeds the capacity of the PDA screen, the increased need for scrolling will decrease the effectiveness of any given layout. Since designing too many menu–icons will increase the amount of scrolling and reduce operational effectiveness, Norman (1991) suggested that for best results one should properly balance the depth and breadth of the menus. Moreover, the function-menu layout should address the sequence, functional group and use frequency of functional items. Sanders and McCormick (1993) pointed out that the LCD touch screen is effective for functional icon manipulation but has poor operational accuracy due to its high sensitivity, especially for users with poor vision. Gessler and Kotulla (1995) suggested that only about 50 (Palm OS) to 75 (Windows CE) words can be shown simultaneously on a PDA screen, with the result that designers must observe more conservative interface requirements than those for desktop platforms. Marcuse et al. (1998) revealed that standard criteria such as font size, color, resolution, and graphics capabilities have been challenged by small-screen size. Tang (2001) stressed that users need more time to learn how to use a PDA software product if it includes more hierarchical configuration levels. Independently, Albers and Kim (2002) noted that the small PDA screen is difficult for users to model mentally, leading to short-term memory overload.

All of the aforementioned factors can affect navigation performance in search operations, particularly in a deeply structured menu–icon layout. Icon design principles that are applicable for large desktop computer displays are not suitable for small PDA screens. Huang et al. (2002) used principal components analysis to evaluate nineteen existing computer icon elements and suggested that meaningfulness and accessibility are two of the most important factors for icon design. In general, a performance measurement is crucial for evaluating usability goals and comparing competitive design alternatives in the context of the usability engineering lifecycle (Nielsen, 1993). Different interface styles may offer different operating performances. Treu (1994) stressed that a good interface design can decrease the user's learning time and lower the probability of error in using the software. Chu (2001) proposed that interface design for tiny screens should aim to simplify content presentation to improve readability, help users navigate system information and avoid loss of direction. Lee and Yoon (2004) defined an adaptive menu that would display items that are most frequently used on the first screen for ease of task selection. Park et al. (2007) further examined the effectiveness of adaptable and adaptive menus for desktop computing scenario and concluded that the adaptable menu system was more efficient. Greater attention has recently been focused on the critical role that sound PDA interface design can play in securing competitive advantage. Unfortunately, many research efforts regarding PDA interface design are still limited to general design rules or guidelines. The integration of interface design with customer requirements is seldom considered. The objective of our research is to propose a useful interface design process that integrates hierarchical clustering analysis (HCA) (Lehmann, 1979) and the technique for order preference by similarity to ideal solution (TOPSIS) in the customer-oriented menu and icon design process for PDA software. Note that the TOPSIS approach is one of the best-known multiple criteria decision making (MCDM) methods (Hwang and Yoon, 1981; Cheng et al., 2003). In this interface design process, the HCA incorporates an analytic hierarchy process (AHP) (Saaty, 1980) to identify and evaluate the critical attributes of the stated customer requirements. TOPSIS is used to perform the competitive benchmarking and to evaluate the resulting design alternatives.

## 2. Procedure for PDA menu–icon interface design

Menu–icon interface design is a creative process that integrates abstract image components into a complete set of physical menu–icon characteristic specifications that satisfy the stated user requirements. Based on this research objective, we created a conceptual framework for PDA menu–icon interface design as shown in Fig. 1. Fig. 1 illustrates the three-stage development process for PDA menu–icon interface design. The stages include (1) identification and analysis of customer requirements, (2) synthesis and generation of feasible menu–icon design alternatives, and (3) evaluation and recommendation of the most suitable menu–icon design option. Stage 1 identifies the critical customer requirements for PDA products by employing a user preference investigation and analysis framework. HCA is used to group the customer requirements as derived from questionnaires and interviews. The analytic hierarchical process is then used to judge the weights for the identified customer requirements. Stage 2 develops feasible menu–icon design alternatives and establishes online prototypes for experimentation and evaluation, consistent with the customer requirements identified in Stage 1. In Stage 3, an experimental design process is conducted to evaluate the operating time and number of errorful clicks for each of the menu–icon design alternatives. The TOPSIS approach is ultimately employed to evaluate the overall operating performance for each of the design options. The conceptual framework for the development process is shown in Fig. 1.

## 3. Identification and analysis of customer requirements

Customer preferences must first be investigated and analyzed to aid the designer's understanding of customer requirements in PDA menu design. The designer can then develop a desirable menu–icon system that will meet customer expectations.

Possible PDA functional menus will first be collected from various sources including discussions, brainstorming, marketing information, the internet and PDA users. A semantic differential method will then be implemented using a questionnaire based on a five-point scale to assess the significance of the functional menus. Points 1, 2, 3, 4 and 5 correspond to very low, low, medium, high, and very high importance. Each tester will assess the functional menus based on six attributes, namely relevance to purpose, flexibility of system adjustment, efficiency of search or inquiry, length of operating time, practicality of functional menus and entertainment value. These attributes were originally derived using the same identification process as for the PDA functional menus. The survey results are then pooled to form a relationship matrix with rows that denote functional menus and columns that are based on these six attributes. Once the matrix has been created, HCA is employed to categorize the functional menus into a hierarchical tree structure. Note that the Euclidean distance and average linkage are used in this research to compute the distances among functional menus.

### 3.1. HCA to categorize customer requirements

Let SFM denote the set of labels or names that identify semantic functional menus.

$$\mathrm{SFM} = \{\mathrm{SFM}_a | a = 1, 2, \ldots, r\}.$$

Similarly, let ATT denote the set of labels or names that identify semantic attributes regarding PDA functional menus,

$$\mathrm{ATT} = \{\mathrm{ATT}_b | b = 1, 2, \ldots, s\}.$$