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Abstract
Mobile phones have become indispensable in our everyday life. The fierce market competition characterized by rapid expansion of advanced functionality and feature is making consumers' mobile phone selections increasingly complex and challenging. In this study, we use Analytic Hierarchy Process (AHP), a multiple criteria decision method, to build a recommendation system for mobile phones selection. AHP provides a structural and easily comprehensible model for making product choices. We empirically evaluate our recommendation system by conducting a controlled experiment that involved 244 mobile phone users. Our analysis results indicate that the use of the proposed system results in higher satisfaction than that associated with the rank-based and equal-weight based benchmark systems.

Keywords: Recommendation Systems, Analytic Hierarchy Process (AHP)

Introduction

Mobile phones have become increasingly indispensable in our everyday life. According to the Pyramid Research, the number of mobile phone users has grown from 170 million in 1996 to 2.5 billion in 2006, showing an average growth of 230 million users per year 0. Similar growths have been observed in Taiwan, where the mobile phone penetration reached 100% in 2006 0. An increasing number of brands and models and the expanded functionality and design have made it more and more difficult for a product to catch the attention of a consumer. Therefore, developing a decision support system that can suggest proper phone models that match user needs is a valuable application.

Since multiple factors may be involved in the selection process, mobile phone selection can be formulated as a multiple criteria decision-making (MCDM) problem 0 that takes into account consumers' preferences or expectations with respect to design, functionality, feature, appearance, or price. This product space is enormous and can be overwhelming for individual consumers, when considering its exhaustive combinations and consumers' bounded rationality.

A system-based approach to support consumers' mobile phone selections is appealing. Recently, web-based recommendation systems have gained much attention due to its ability to reduce information overload and increase user satisfaction (Liang, et al., 2006). Designing and evaluating a recommendation system capable of automatically performing efficient and consistent product analysis and comparison on the basis of consumers' preferences or constraints can greatly support and improve their mobile phone selections. The use of an established MCDM method or technique to construct such recommendation systems is particularly desirable because of its well-formulated analytical basis and systematic analysis. Such system-based approaches can mitigate the stringent search efforts commonly required of consumers and are likely to increase user satisfaction.

In this study, we employed the analytical hierarchy process (AHP) to design and implement a web-based recommendation system that supports consumers' mobile phone selections on the basis of their preferences and constraints. Choice of AHP was advantageous because of its explicit specifications in analysis, robust built-in consistency assessments, validated measurement scale, intuitiveness, and ease of use 0. The system was then evaluated empirically to examine its effect on user satisfaction. Specifically, we conducted a controlled experiment that involves 244 current mobile phone users. The AHP-based system was compared with two benchmark systems that were built upon rank-based and equal-weight based analysis, respectively.

The results show that the recommendation system that used AHP to analyze user preference can effectively increase user satisfaction. This study contributes to recommendation system research and practice by demonstrating the feasibility and value of incorporating established MCDM methods to support complex product selection problems, hence highlighting a promising direction for recommendation system research.

The remaining of the paper is organized as follows: Section 2 analyzes mobile phone selections by consumers, provides an overview of AHP, and highlights our motivation. Section 3 analyzes mobile phone selection in accordance with the general AHP process for decision making. Section 4 describes our architecture design and system implementation, followed by our hypotheses and experimental design in Section 5. Section 6 highlight important evaluation results and discusses their implications. We conclude the paper in Section 7 with a summary and discussions of some future research directions.

Problem Domain and the AHP Method

Nature of Mobile Phone Selections and Personalized Recommendation

The fast-growing product variety together with the continually compressed product cycle has made mobile phone selection increasingly challenging to consumers. The resulting product (search) space is enormous and complex, thus making manual approaches to product search and comparison difficult, if effective at all. In contrast, a system-based approach is appealing because it supports systematic evaluation and consistent comparison while mitigating the cognitive efforts commonly required of consumers in mobile phone selections.

Recommendation systems are computer-based software that can identify a few choices from a large space of alternatives. They can be classified as personalized or non-personalized 0. A personalized recommendation system is appropriate for supporting individual consumers' decision, because it considers their respective preferences and constraints. A handful of analytical methods have been studied for developing recommendation systems, some analyzing important attributes or contents, others making use of collaborative filtering or anchoring at item correlation analysis. Most previous research in recommendation systems seems to focus on assisting an individual to search or locate prospective products presumably satisfactory or relevant to his or her preference. However, discussions pertaining to product selection and comparison, equally important in the consumer purchase process and arguably more challenging than product identification, have been limited 0.

For consumers, performing mobile phone selection and comparison is complex because of the wide variety in terms of brand, vendor, design, functionality, and feature. Choosing an appropriate phone often requires significant effort for comparison and evaluation. While many consumers can access or locate important information about different mobile phones with relative ease (such as from product brochures and vendors' websites), performing consistent and efficient evaluations of competing phones however remains challenging. It is particularly challenging for an online seller to identify consumer needs and make proper recommendations.

Since mobile phone selection involves many attributes, it is a MCDM problem. Different MCDM methods have been developed and empirically tested in various decision-making scenarios. Of particular importance is AHP, which has been used in complex decision-making tasks including system/software selection 0, investment risk assessment 0, organization resource allocation 0, automobile purchase 0, project evaluation 0, predictive maintenance programs 0, vendors selection 0, assess website quality 0 and decision-support system development 0. In essence, AHP integrates an individual's judgments in a multi-dimensional space and produce a single overall ranking of the competing products under consideration. The following section provides an overview of AHP.

An Overview of AHP

AHP is a well-established multi-criteria decision support method capable of generating an optimal choice from a set of alternatives, in accordance with specified evaluation criteria or user-provided preferences 0. General applications of the AHP method involve three sequential phases—decomposition, comparative judgment, and priority synthesis 0.

In the *decomposition* phase, the target decision task is formulated as a hierarchical structure, with the highest level representing the overall objective and lower levels denoting the main evaluation criteria, sub-criteria, and alternatives, respectively. In the *comparative judgment* phase, a comparison matrix is constructed at each level on the basis of the user's pair-wise assessments of the criteria or sub-criteria under consideration. In the *priority synthesis* phase, a composite weight (score) is calculated for each alternative or product, using the preference extracted from the matrix constructed in the previous phase. The resulting composite weights, in turn, lead to a relative standing of the alternatives or products under consideration, typically on a ratio scale, and therefore can be used to select an optimal alternative or product in a systematic and consistent manner. The general process for applying AHP in a decision problem is as follow:

Step 1: Create a hierarchical structure of the decision problem by recursively decomposing it into a set of criteria. Specifically, the decision problem is represented using objective, criteria, and alternatives. The objective is the root the hierarchy, explicitly stating what it is to be achieved or optimized. Beneath the objective are the criteria, each of which is derived from progressive decompositions of the target decision problem. The alternatives reside at the bottom of the hierarchy, denoting the competing products under consideration; i.e., from these alternatives an optimal is to be selected. The objective and the criteria jointly form a tree in which a criterion can be further decomposed into a set of sub-criteria until they can be readily used to evaluate the attributes of each alternative (or product) directly. An AHP hierarchy is usually constructed by domain experts; the exact number of levels in the hierarchy often is determined by the experts' analysis and domain knowledge as well as the complexity of the decision problem.

Step 2: Assess the criteria (i.e., key product attributes) using pair-wise comparisons to

determine their relative importance, and then calculate the principal eigenvector (a mathematical approach used by AHP) of the matrix obtained from the comparative assessments by the user. This procedure determines the relative priority (i.e., importance) of each decision criterion with respective to that at the adjacent higher level in the hierarchy.
Step 3: Transform the comparison results into corresponding link weights in the AHP hierarchy and then evaluate the consistency in the comparisons by the user. A small consistency ratio (CR) is preferred. According to Satty (1980), a threshold of less than 0.1 is generally appropriate. In principle, the pair-wise comparisons are repeated until the CR satisfies a specified threshold. Following Satty's recommendation, we continue pair-wise comparisons by asking the user to perform the pair-wise comparison procedure all over again, when the CR is greater than 0.1.
Step 4: Use the resulting link weights to evaluate each alternative or competing product. In most cases, we multiply the weights of criteria in each branch of the tree. The product of the weights therefore represents the user's preference and is then mapped to each attribute of the alternative or product. An attribute of each alternative or product has a score which can be directly compared with that of other alternatives or competing products. For each alternative, we multiply the score and the branch weight and thereby obtain a summation that represents the overall assessment of this particular alternative. The resulting scores then can be used to rank the alternatives or competing products under consideration, thereby generating an optimal recommendation.

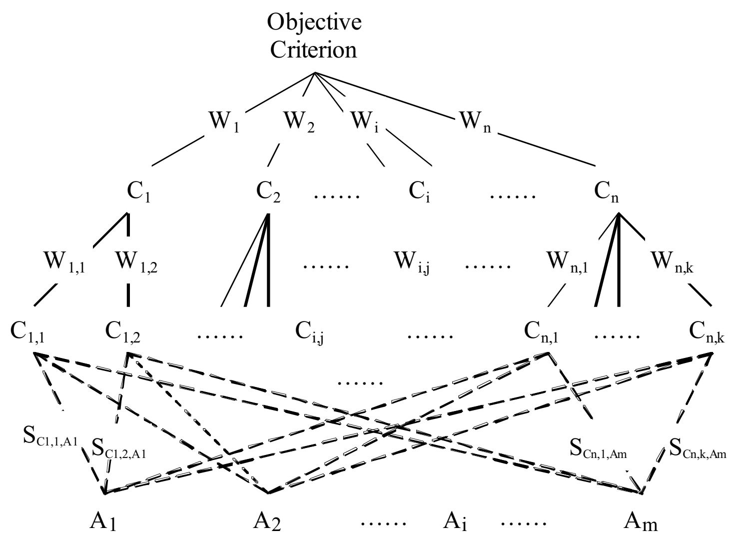

Figure 1: A Typical Structure of AHP Hierarchy

Figure 1 illustrates an AHP hierarchy. The root represents the decision objective; the leaf nodes denote alternative products Ai; and the decision criteria C_i and $C_{i,j}$ reside in between. The solid lines connect the criteria and the objective to form a decision tree, whereas the dash lines link alternatives to the leave nodes of the tree. The link weights W_i and $W_{i,j}$ are determined by the user's pair-wise comparisons of C_i and $C_{i,j}$, respectively. $SC_{i,j,\ Ai}$ is the score of alternative A_i, with respect to criterion $C_{i,\ j}$; $W_{i,j} * SC_{i,j,\ Ai}$ is the portion of the score that the criterion receives in the overall evaluation of the competing products. This value is then propagated upwards until reaching the root of the tree.

Motivation

Design and implementation of recommendation systems for consumers' mobile phone selections has not been duly studied, particularly using established MCDM methods or techniques. According to our analysis, AHP is a promising method for building effective recommendation systems. Most previous AHP studies focus on problem analysis/formulation or system design/implementation; as a result, issues concerning user experience are seldom addressed. User experience is critical to system adoption and usage by target users 0. Of particular importance is user satisfaction which has profound and ultimate impacts on system success 0. Doll and Torkzadeh 0 advocates examining user satisfaction from both information and system perspectives, using separate measurement scales for these related but distinct constructs. Liang, et al. (2006) also used both system and content to assess user satisfaction with personalized recommendation content. Therefore, we followed the line and evaluated user satisfaction on information content and system associated with the use of the proposed recommendation system and compared them with those commonly used methods as our benchmark.

Construction of the AHP Model for Mobile Phone Selection

A key to an AHP-based system is to construct a good model that captures the major attributes and their proper weights for decision making. Therefore, the first step of the study was to obtain a consumer's preference or constraints through a pair-wised comparison process. In this section, we describe the process by which the AHP model was constructed.

An AHP Hierarchical Tree for Mobile Phone Selection

In order to obtain the relative importance of different criteria, we first identified major criteria for mobile phone selection by an extensive review of product description documents, industry or customer reports, major business magazines, and leading vendors' websites. Our findings point to five important selection criteria—brand, price, hardware feature/functionality, basic built-in functions, and extended built-in functions. A random survey was then conducted to determine the relative weights of these attributes. Among the 98 individuals contacted, 48 of them completed the survey questionnaire, showing a 48% effective response rate. Based on their responses, we chose the top 5 attributes of each decision criterion; i.e., hardware feature, basic built-in functions, and extended built-in functions. The alpha values were 0.67 for hardware, 0.83 for basic built-in functions, and 0.88 for extended built-in functions. Judged by the commonly recommended threshold of 0.7, these attributes exhibit appropriate internal consistency. Figure 2 depicts the resulting hierarchical structure for our mobile phone selection from the analysis.

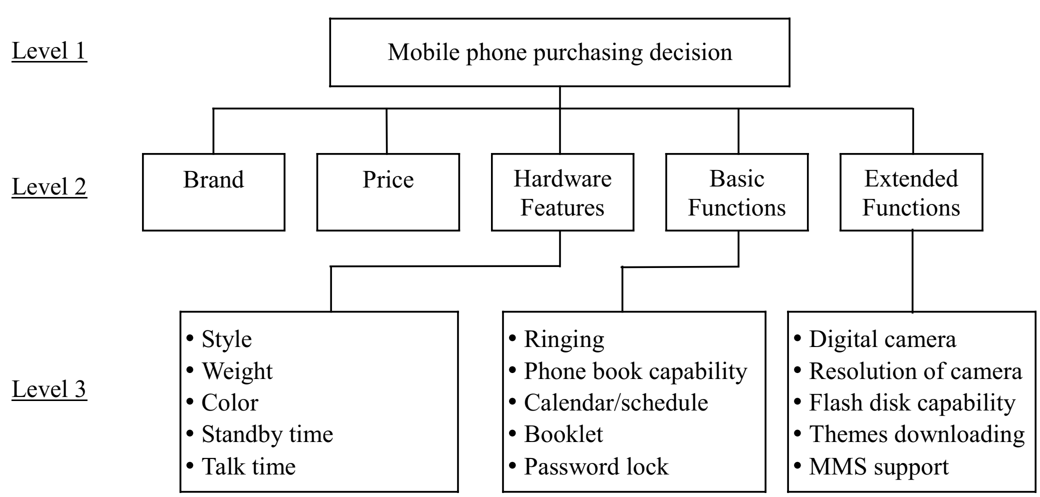

Figure 2: Analysis of Mobile Phone Section – A Hierarchical Representation

Brand: In general, brand refers to name, term, design, symbol, or any other feature that identifies one seller's good or service as distinct from those of other sellers 0. A brand may identify one product, a product family, or all products of a seller. According to Boyd and Mason 0, brand is as important as key product attributes and should be assessed in conjunction with product attributes. We therefore included brand as a key decision criterion for mobile phone selection. We targeted popular brands that include Nokia, Motorola, Samsung, SonyEricsson, and LG. Together, these brands accounted about 80% of the global mobile phone market in the second quarter of 2006 0. Our evaluation also included four leading brands in the Taiwanese market; i.e., Simens, BenQ, OKWAP, and Panasonic.
Price: Price is critical to the consumer purchase decision and has been commonly used as a quality indicator 0. According to Mitra 0, most consumers evaluate product attributes in conjunction with price. We therefore included price as an important criterion for mobile phone selection.
Hardware Features: Consumers often pay close attention to the hardware features when selecting mobile phones. According to our analysis, several features are essential, including appearance design, weight, color display and resolution, talk-time, and standby-time. We therefore included these five hardware features.
Basic Built-in Functions: Mobile phones vary considerably in their basic built-in functions. Our analysis showed many consumers valued functions such as polyphonic ring tones, phone book capability, booklet, calendar/schedule, and password lock. We therefore included them in our analysis.
Advanced Built-in Functions: In addition to basic functions, all mobile phones have advanced functions for increasing customer value and product differentiation. Our analysis showed that several advanced functions were important, including digital camera and image resolution, flash disk extension capability, themes downloading, and multimedia messaging service. Accordingly, we included them in our analytical structure.

Normalization of Attribute Measurement

AHP captures a user’s preferences through systematically comparing different attributes. For example, both color and weight may be important hardware features; but the challenge is to decide which color or which weight is “better” and make the scale of the resulting weights to be comparable. A normalization process is necessary to transform different attributes to a standard scale. In this study, we measured the investigated attributes using a scale ranging from zero to ten. We classified the attributes into four categories, each of which has its own measurement. These categories were price, subjective attribute, dichotomous attribute, and scale attribute. Details of our measurements are as follows.

To assess price, we extended Positive Trapezoidal Fuzzy Numbers, a common method for analyzing the impact of price in consumers’ purchase decision making. Specifically, we proposed Positive Triangular Fuzzy Numbers, an extension that requires three user-provided parameter values: the maximal price (c), the minimal price (a), and the most preferred price (b). The membership function $\mu\tilde{A}(x)$ is defined as follows:

$$\mu\tilde{A}(x) = \begin{cases} 0 & x < a \\ \dfrac{x-a}{b-a} & a \le x \le b \\ \dfrac{x-c}{b-c} & b \le x \le c \\ 0 & x > c \end{cases} ;\ 0 < a < b < c$$

We examined subjective attributes using consumers’ responses to brand, color, and style.

These attributes were measured on a 5-point Likert-scale. A dichotomous objective attribute denotes the presence versus the absence of a function or feature in a mobile phone; e.g., supporting or not supporting polyphonic ring tone, calendar/schedule, booklet, password lock, digital camera, theme download, or MMS. The presence of a function or feature in a mobile phone was represented by a score of ten, while the absence of which was given a score of zero. In addition, scale objective attributes refer to those that can be assessed by a continuous measurement, such as weight, stand-by time, talk time, phone book capability, camera resolution, and flash disk capability. Because of the continuum nature of these functions or features, we used a ranking list to compare different mobile phones.

Architecture Design and System Implementation

In order to examine the value of the AHP approach, a prototype system was implemented to show the feasibility and an experiment was conducted to compare with two benchmarks. Figure 3 depicts the conceptual architecture of the prototype system.

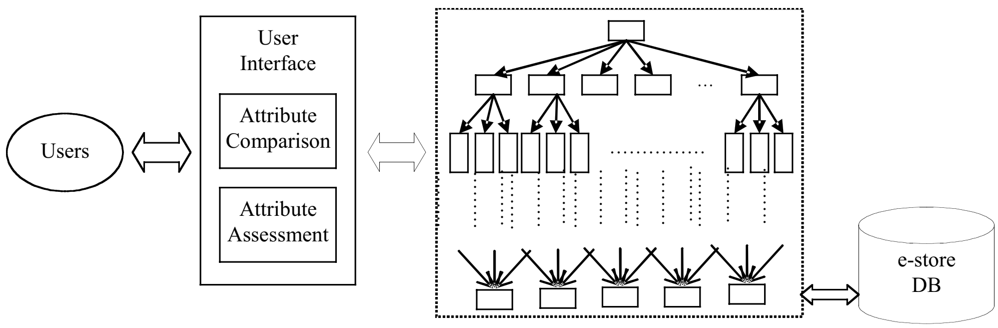

Figure 3: Architecture of the Proposed AHP-based Recommendation System

Our system allowed the user to perform pair-wise comparisons of different mobile phones (i.e., using their attributes), thereby obtaining his or her preference or constraints. The e-store database in Figure 3 contains data about the important characteristics or properties of each mobile under examination, with adequate search engine support. Through measurement normalization, our system transforms different types of attributes into a uniform scale. Hence, our system can select and recommend the most appropriate mobile phone to a consumer, using its built-in analysis, and the user-provided preference and assessments.

Evaluation of the AHP-based System

The APH-based system was evaluated on its impact on user satisfaction by comparing with two commonly used recommendation mechanisms, the rank-based and equal-weight approaches. Both information satisfaction and system satisfaction are considered important and measured using separate validated measurements. In our study, satisfaction on information refers to a user's satisfaction with the recommendations by a system, whereas satisfaction on system is concerned with the functional design of the system, such as user friendliness, ease of use, and interface design 0. Specifically, we test the following hypotheses:

H1: Subjects exhibit higher information satisfaction when using the proposed AHP-based recommendation system than using the benchmark rank-based system.

H2: Subjects exhibit higher system satisfaction when using the AHP-based recommendation system than using the benchmark rank-based system.

A controlled experiment was conducted, which can be illustrated as follows:

Experimental Design: We adopted a randomized between-groups design. In the treatment group, subjects were supported by the AHP-based recommendation system, whereas their control-group counterparts used the benchmark rank-based recommendation system. Subjects supported by the AHP-based system had to assess all the attributes pertaining to each investigated decision criterion. In contrast, subjects using the rank-based system were presented with only the top 5 attributes of each criterion. Our study also included a system built upon an equal-weight analysis which provides the necessary baseline in our comparative evaluations.
Subjects: We constructed from multiple sources a pool of mobile phone users and then randomly selected 500 individuals and contacted them individually to solicit their voluntary participation in our study. Among them, a total of 266 individuals agreed to take part in the experiment. We randomly assigned each subject to either the treatment or the control group. Most of our subjects had university or graduate degrees, used the Internet extensively (averaging 3 hours or more a day), and had used mobile phones for at least four years.

The AHP-based system lists all pair-wise comparisons of the product attributes pertaining to each criterion; e.g., hardware feature and functionality, basic built-in functions, or extended built-in functions. When making a pair-wise comparison, a subject had to explicitly specify the relative importance of the two presented attributes by indicating their particular values on a 9-point Likert scale. We illustrate these pair-wise comparisons using attributes A and B as an example in Table 1.

Table 1: Scale for Pair-Wise Comparison between Two Attributes

Comparative Assessment	Value
A is equally important as B	1
A is slightly more important than B	3
A is fairly more important than B	5
A is strangely more important than B	7
A is absolutely more important than B	9
A is slightly less important than B	1/3
A is fairly less important than B	1/5
A is strongly less important than B	1/7
A is absolutely less important than B	1/9

Our benchmark system is based on rank-based analysis which is generally considered reliable and easy to use 0. As Watson and Buede 0 noted, rank-based analysis is an essential step for soliciting from a decision maker the exact weight of different attributes. For each investigated criterion, our benchmark system lists all the attributes and asked the subject to identify the top 5 attributes in a descending order. We adopted the following weights of the resulting prioritized attributes: 5/15, 4/15, 3/15, 2/15, and 1/15, respectively. In addition, the baseline system assigns an equal weight to all the attributes, thus allowing our comparative evaluation of the proposed AHP-based system and the benchmark rank-based system.

Dependent Variables: Our evaluation concentrates on user satisfaction. Following the approach by Jefferson and Nagy 0, we studied user satisfaction using data obtained from a controlled experiment and a questionnaire survey. We explicitly distinguished information satisfaction and system satisfaction and measured them using separate items adapted from DeLone and McLean 0. Table 3 lists the specific items that we used to measure information satisfaction and system satisfaction, respectively.

Experiment Flow: Figure 4 describes the overall flow of our evaluation experiment. Upon entering the experiment website, each subject was explicitly informed of the study's objective and our intended data analysis and management. We specifically emphasized anonymity in data collection and assured all subjects of our analyzing the data at an aggregate level, not in any personally identifiable manner. Subjects were asked to complete a pre-study questionnaire which is designed to collect important demographic information of each subject.

In the experiment, each subject was first asked to indicate his or her preference concerning brand, price, color, and appearance. Subjects were then randomly assigned to the treatment group or the control group. In the treatment group, a subject was presented with pair-wise comparisons of all the attributes that pertain to each investigated decision criterion. The sequencing of the pair-wise comparisons begins with hardware feature and functionality, followed by basic built-in functions, and then extended built-in functions. Each system selected and recommended five mobiles phones in accordance with the subject-provided assessments and responses and presented them to the subject in a descending order.

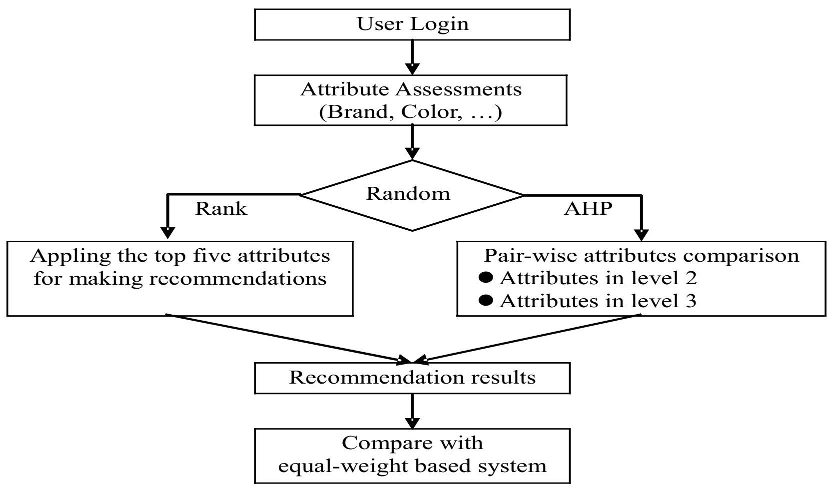

Figure 4: Overall Evaluation Experiment Flow

Each subject was then asked to indicate his or her satisfaction with the recommendations by the system, in relation to those made by the baseline (equal-weight based) system. In addition, each subject had to indicate his or her satisfactions with the system as well. The items for measuring information satisfaction or system satisfaction used a 5-point Likert scale, with 1 being highly satisfied with the system (AHP-based system or benchmark system) and 5 being highly satisfied with the baseline (equal-weight-based) system.

Pre-test: We conducted a pretest to fine-tune the experiment design and data collection procedure. We also used the pretest data to revalidate our survey instrument. A total of 14 mobile phone users voluntarily took part in the pretest which proceeded according to the experiment procedure described. By analyzing the participants' responses and suggestions, we made several (minor) changes to our study design. First, we replaced talk-time and standby-time with battery capacity which essentially determines both talk-time and standby-time. Second, we removed digital camera resolution from the extended built-in functions because it requires digital camera and its inclusion as an extended function may confuse subjects when performing pair-wise comparisons. In addition, we adopted qualitative descriptions in the AHP measurement scale primarily because of the increasing comprehension by subjects.

Evaluation Results and Discussions

A total of 266 current mobile phone users participated in the experiment; 14 of them failed to complete the experiment and therefore were removed from our analysis. The treatment group has 132 subjects and the control group has 120 subjects. In the treatment group, 8 subjects showed a consistency ratio (CR) greater than the commonly recommended threshold of 0.1 and therefore were excluded from our analysis, making the effective treatment-group sample size 124. Our subjects range between 20 and 40 years old in age and show a gender distribution of approximately 66-to-34 in favor of males. We observe no significant between-groups differences in gender distribution, education background, and daily Internet usage. Subjects in the treatment and control group have comparable mobile phone experiences and indicate a similar frequency of changing mobile phones.

Analysis of Reliability: We examined the reliability of our measurements in terms of Cronbach's alpha. The alpha values range between 0.86 and 0.92, significantly higher than the common threshold of 0.70. Therefore, the measurement instrument exhibits satisfactory reliability.

Analysis of Convergent/Discriminant Validity: We examined the convergent and discriminant validity of our measurement instrument by performing principle components factor analysis. As shown in Table 2, the loadings of the items that measure the same construct are significantly higher than those for measuring the other construct. The factors extracted from our analysis account for 80.36% of the variances in the AHP-based system and 73.65% of the variances in the benchmark system. According to our results, the instrument exhibits satisfactory convergent and discriminant validity.

Table 2: Analysis of Measurements' Convergent and Discriminant Validity

Measurement Item	Treatment Group		Control Group	
	Factor 1	Factor 2	Factor 1	Factor 2
S-1	**0.86**	0.31	**0.87**	0.22
S-2	**0.86**	0.23	**0.82**	0.27
S-3	**0.90**	0.23	**0.90**	0.16
S-4	**0.71**	0.51	**0.71**	0.31
S-5	0.33	**0.86**	0.31	**0.77**
S-6	0.34	**0.75**	0.34	**0.77**
S-7	0.22	**0.89**	0.10	**0.84**
S-8	0.23	**0.87**	0.22	**0.82**
Percent of Variances Explained	80.36 %		73.65 %	

Hypothesis Testing Results: Table 3 summarized important descriptive statistics of our subjects' assessments. AHP-based recommendation system averages 3.20 in information satisfaction and 3.53 in system satisfaction. In contrast, the benchmark rank-based system averages 3.06 in information satisfaction and 3.66 in system satisfaction. According to our analysis, subjects are significantly more satisfied with the recommendations by the AHP-based system than with the benchmark system. For system operations, our subjects show a higher satisfaction with the benchmark system than the AHP-based system. One plausible explanation may be the differences in the inputs required by the systems. When using the AHP-based system, subjects must provide their assessments to all pair-wise comparisons. Such comparisons are tedious and cognitively demanding, and therefore may have affected their satisfactions with the system adversely.

Table 3: Descriptive Statistics of Satisfaction Evaluations – Treatment versus Control Group

		Treatment Group		Control Group	
		Mean	S.D.	Mean	S.D.
Satisfaction with Recommendations	System's recommended phones meet my requirements.	**3.15**	1.02	2.95	0.97
	System's recommended phones satisfy my specifications.	**3.23**	0.96	3.16	0.92
	I am satisfied with the precision of system's recommended phones.	**3.07**	0.96	2.93	0.99
	Overall, I am satisfied with the system's recommendations.	**3.35**	1.06	3.21	1.06
	Average	**3.20**	0.90	3.06	0.87
Satisfaction with System	I find that the system's operations are clear.	3.56	0.95	**3.63**	1.04
	I find that the information presented by the system is clear.	3.44	0.98	**3.58**	0.98
	The system's user interface is user-friendly.	3.52	1.01	**3.68**	0.96
	Overall, I am satisfied with the systems ease of use.	3.60	0.98	**3.76**	0.93
	Average	3.53	0.87	**3.66**	0.82
Satisfaction with Equal-Weight based System		**3.15**	1.03	2.88	1.10

To test H1, we performed one-sample t-test to confirm whether or not the average information satisfaction is equal to 3. Table 4 summarizes our results, using the equal-weight based system as a baseline. The increment in information satisfaction (i.e., satisfaction with the recommendation) associated with the use of the AHP-based system is significant statistically; i.e., *p-value* less than 0.01. We observe an improvement in information satisfaction associated with the use of the benchmark system, which however is not significant statistically. We further analyzed the increase in information satisfaction at the measurement item level (see Table 5). In the treatment group, we observe significant differences in two of the information satisfaction items. Overall, our data support H1 and suggest the use of the AHP-based system generating higher information satisfaction than the benchmark system.

Table 4: Analysis of Satisfaction with Recommendations – Treatment versus Control Group

Construct	Treatment Group			Control Group		
	t-value	d.o.f.	p-value	t-value	d.o.f.	p-value
Satisfaction with Recommendation by System	2.48	123	0.01	0.80	119	0.43

Table 5: Comparative Analysis of Satisfaction with Recommendations – by Measurement Item

Measurement	Treatment Group		Control Group	
	t-value	p-value	t-value	p-value
System's recommended phones meet my requirements.	1.59	0.11	-0.56	0.57
System's recommended phones satisfy my specifications.	2.70	0.01	1.89	0.06
I am satisfied with the precision of system's recommended phones.	0.84	0.40	-0.74	0.46
Overall, I am satisfied with the system's recommendations.	3.64	0.00	2.15	0.03
Compared with Satisfaction with of Equal-Weight based System	0.17	0.12	-1.24	0.22

We also used one-sample t-test to test H2, using the equal-weight based system as a baseline. As shown in Table 6, the improvement in system satisfaction resulting from the use of the AHP-based system is significant statistically. We observe a similar result with the benchmark system. According to our comparative analysis, subjects show a higher satisfaction with the rank-based system than with the AHP-based system. Hence, our data does not support H2; i.e., use of the AHP-based system is not associated with higher system satisfaction than the benchmark system. Further analysis shows that users need to provide less input when using the rank-based system than using the AHP-based system. The tedious pair-wise (attribute) comparisons required by the AHP-based system complicate subjects' use of and interface to the AHP-based system. Consequently, subjects show higher system satisfaction with the rank-based system. We also examined the increase in system satisfaction at the measurement item level. As summarized in Table 7, the satisfaction improvement resulting from the use of either the AHP-based system or the benchmark system over the baseline system is significant statistically in all items.

Table 6: Analysis of System Satisfaction – Treatment versus Control Group

Construct	Treatment Group			Control Group		
	t-value	d.o.f.	p-value	t-value	d.o.f.	p-value
Satisfaction with the System	6.806	123	0.00	8.840	119	0.00

Table 7: Comparative Analysis of Information Satisfaction – by Measurement Item

Measurement	Treatment Group		Control Group	
	t-value	p-value	t-value	p-value
I find that the system's operations are clear.	6.53	0.00	6.64	0.00
I find that the information presented by the system is clear.	5.07	0.00	6.50	0.00
The system's user interface is user-friendly.	5.70	0.00	7.68	0.00
Overall, I am satisfied with the systems ease of use.	6.89	0.00	8.97	0.00

Overall, our results suggest the feasibility of using the AHP method to build effective recommendation systems for mobile phone selection. As shown by our empirical evaluation, consumers are satisfied with the recommendations by such systems which however may be to streamline its input requirements together with effective interface designs.

Conclusion

In this study, we design, implement and evaluate an AHP-based system for recommending appropriate mobile phones to consumers on the basis of their preferences and constraints. We examine the effectiveness of the proposed system by conducting a controlled experiment that include a salient rank-based system as a performance benchmark as well as an equal-weight based system that provide the necessary baseline for our comparative evaluation. Our evaluation focuses on user satisfaction with an explicit distinction between information satisfaction and system satisfaction. Our evaluation involves 244 mobile phone users and use validated measurements. According to our comparative analysis, consumers are more satisfied with the recommendations by the AHP-based system but exhibit higher system satisfactions with the benchmark rank-based system.

From a research perspective, our study investigates the feasibility of using the AHP method for mobile phone selection by properly addressing its inherent limitations, including transformation of qualitative attributes to quantitative scales and normalization of measurements. For practice, we design and implement a workable recommendation system and demonstrate the effectiveness empirically. Our architecture design and implementation are scalable and can be extended to support similar product search problems. Concisely, our research has shown that AHP method can be applied as a core algorithm of recommendation system. It might be also contributive to software agent design in electronic commerce research. An agent is also called an intelligent agent when it possesses the properties of autonomy, social ability, reactivity, and pro-activeness (Wooldridge and Jennings 1994). It could be used to support decision making of EC (Liang and Huang 2000). In this case, we need some methods to catch users' preferences in agents and let agents' autonomous behavior could stand for a real human. In our research, AHP has been used to represent users' preferences and make a suitable decision for users. In a rationally reasoning, AHP could be the core algorithm of an autonomous agent in EC environment.

Although we have applied AHP in a recommendation system effectively, there are some original problems of AHP method needed to be improved. How to simplify the process of pair-wise comparisons will be the critical one. In our research results, users are not satisfied with the system usage, and this is because AHP method needs tedious and complex pair-wise comparisons to get users' preferences. By increasing development information technology, data mining would be a feasible solution. Data mining technology could be used to analyze users' behavior and preference. Combining data mining and AHP, we might develop a more effective automatic recommendation system.

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