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An Empirical Model for Information Retrieval System Evaluation: The User's perspective

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Abstract

The aspect of time has become an issue since computers were introduced into management studies and thus highlights the need for efficient paradigm that will enable easy access to information, with much ease. But this is not the case yet, since finding the desired search engine and learning how to use them for this purpose is still time consuming. The continued dominance of measures for use in the system-centered aspect of IR evaluation, which is weak for use in user-centered IR system evaluation process, remains a challenge. Therefore the purpose of this study is to present usable measures through using an empirical from user's perspective for use in the evaluation of IR system. The survey method, a robust multivariate mathematical model and the factor analytic method were experimented upon. Results showed that the model presented is promising concerning the challenges highlighted. Therefore user's own knowledge, experience and searching abilities could be harnessed and implicated in IR design and evaluation. This study therefore serves as a test bed and guide to studies in this area, which results could contribute immensely to the overall improvement of the system. However, more data and a larger sample size are required to verify the proposed model in future, with other extraction techniques.

Keywords: Computers, IR system, Search engines, System-centered paradigm, User-centered paradigm, Multivariate mathematical model, factor analytic methods, evaluation

1. Introduction

The aspect of time became an issue when computers were introduced into management studies. As a result two major generations of economies were born because of the impact of the computer. While one of them was driven by automated electronic data processing (EDP), the other one was by the database processing system (DPS) (Thierauf 1973; Codd 1970; Akinyokun & Adejo 2009; Date 198, 1982). The EDP emphasized the syntax of data rather than both the semantics and pragmatics of data. In this era the meaning of data was realizable during the run time of computer programs. Moreover, the EDP systems were developed independent of one another and direct interactions with computers were only the exclusive preserve of computer engineers and operators. The flow of data from one system to another was carried out offline (Akinyokun & Adejo 2009). In the DPS era things were done differently, since its developmental process inspired the concept of data abstraction mechanism. This today has brought about the issue of semantics and functional database modeling techniques (Chen 1976; Smith & Smith 1977; Kent 1978;

Brodie 1980; Nijssen 1981; Hammer & Mcleod 1981; Grithuysen 1982; Stocker 1981). As a follow up to this success, the development of user friendly, interactive and menu driven computer systems was spurred. Hence, nowadays there are several types, sizes of special purpose driven computer systems. Today, desktop and laptop computers; distributed database systems; knowledge base systems and the practical implementation of computer networks are ubiquitous. The immense breakthrough in computer networking in the last three decades has lead to the evolution and revolution of the Internet technology. This has no doubt brought along many products and services such as electronic mail, World Wide Web, electronic business and so on. The world has indeed been turned into a global village where computer language has provided a common platform that is versatile and robust for business transaction world wide (Akinyokun & Adejo 2009).

A major challenge with this "blessing" - the Internet is the need to locate the right information, in terms of how relevant it is vis-à-vis the information need of the user. As a result the importance of archiving and information finding has become an issue not to be taken for granted. Thus with break through in information and communication technology it is now very possible and practicable to store large amounts of information; but finding the one that is useful from such collections have become a necessity. This served as the build up to the two major reasons among others that was responsible for the emergence of the field of Information Retrieval (IR) in the 1950s. First, the need for information and secondly the requirement to quickly find a desired document (which is expected to contain relevant information that satisfies the need of the user) among many files (Yoann & livier 2001). These challenges still remain a major aspect of concern in information retrieval. Over the last forty years, the field has matured considerably, and as a result, several IR systems have been developed for use on everyday basis by a wide variety of users (Amit 2001). One of these IR search paradigms is the search engine, which is the commonest of them all, hence its use in this study (Pasca & Harabagiu 2001; Liaw & Huang 2003; Castillo & Davison 2010). Others include Information support and seeking system (Toms & O'Brien 2009), Question and answering system (Ong *et al.* 2009) and even recommender systems types of IR paradigms.

In (Beigi *et al.*1998), it is reported that search engines are the most powerful resources for finding information on the rapidly expanding World Wide Web (WWW). Thus they have a global active reach of about 89.5% of all users of the WWW (Rubel *et al.* 2009). The integration of such search tools enables the users to access information across the world in a transparent and efficient manner. Recent studies have also shown that majority of Web page accesses are referred by search engines, hence search engines since their arrival in the early 90's, have particularly become an indispensable tool in the everyday life of Internet users (Cho & Roy 2004). But finding the desired search engine and learning how to use them is still time consuming. For this reason and with a global phenomenon of this magnitude it is only worth the while to give IR systems closer and regular examination. Clearly, there is therefore a need for consistent user-centric studies over time. This is with a view to present IR systems that meet this all important user's requirement, hence this study promises to be a contribution.

2. Motivation

The interactive nature of IR system poses many challenges to the system-centered (traditional) (SC) approach to IR system evaluation (Dunlop 2000; Borlund 2003). This brought about the need to employ an alternative approach for its evaluation. However, the degree of interactivity currently being exhibited by IR systems has also introduced a fundamental problem for the SC approach. The problem is that of modelling end-user's user-system interaction. This has to do with the issue of interactivity, which the SC approach to IR evaluation is not able to handle. More frequently the SC has been used to deal only with the problem of measuring the effectiveness of an underlying algorithm (engine) (Dunlop 2000), but with less attention to user aspects. The challenge for interactive evaluation in IR is to connect these types of evaluation: engine performance and suitability for end-users (Dunlop 2000). By and large, Information System's (IS) evaluation, especially in IR domain is an important issue for stakeholders, although very difficult to evaluate (Mandl 2008). Many methods have been developed over the years to evaluate one IS or the other; hence there is yet no unique model that can be used to evaluate all kind of IS (Islam 2009). In the same vain, there is yet no categorical empirical model, resulting from a user-oriented modelling paradigm to evaluate user-system interactivity of search engines (IR system). Existing metrics such as precision and recall and their variants are only usable to evaluate the performance of search engines and from the system's perspective, but not adequate to evaluate IR systems' performance from user's perspectives (Kumar *et al.* 2005).

In IR community, various quality measures for search engines evaluation have been investigated. Their findings include the fact that Web search engine's quality can not be measured by just retrieval effectiveness (the quality of the results). In addition, factors that influences user satisfaction in information retrieval has been investigated and reported. Results from the investigation revealed that user satisfaction is a subjective variable, which can be influenced by several factors. The rationale of evaluating IR algorithms, and the applicability of proposed novel evaluation methods and measures, have been examined and suggested in literature. Also investigated are factors, which should contribute to the choice of search engines and their effects on information-seeking behavior (Kekalainen & Jarvelin 2005; Dujmovic & Bai 2006; Jenkins 2011; Lewandowski & Hochstotter 2008; Arapakis & 2008; Al-Maskari & Sanderson 2010). In (Dujmović & Bai 2006), a comprehensive model for quantitative evaluation and comparison of search engines was presented. The model is based on the LSP method for system evaluation. The basic contribution of the research is the aggregation of all relevant attributes that reflect functionality, usability, and the performance of search engines. The obvious challenge with these efforts to mention but a few is that users are excluded from participating in the research. This confirms the report of (Mandl 2008), that users are often assumed as abstraction in IR system evaluation.

Thus the call for a shift in paradigm from the SC approach to a better way of assessing IR system (Dunlop 2000; Belkin 2008; Paul 2009), from user's perspective using the user-centered (UC) approach. The argument has been that with a holistic approach to IR evaluation, there will be increase in the usefulness (in terms of impact), usability (in terms of assistance) and pleasurability (satisfying the information need of users) of IR use (Belkin 2008). However, it has been identified that the research effort that will bring about this will be very substantial. Underpinning this is the fact that predicting relevance in information retrieval is a hard enough task, but predicting utility (user satisfaction) is a different challenge entirely, which will not be and easy task. However, the success would be worth it (Paul 2009). Therefore, this study seeks to contribute through suggesting and experimental model with its measures using a user-centered approach, which was successfully used to assess IR system from user's perspective in (Akhigbe *et al.* 2011b). This is in order to lend a voice to the call for a paradigm shift. It is expected that suggested measures will be usable for user-related studies in IR, and thus according to (Lewandowski & Hochstotter 2008), contribute to the development of better search systems that give the user the best possible search experience.

3. Aim and objective of study

To underscore the purpose of this effort, two questions that borders on the philosophy of this study are: what are the factors to use in IR system's evaluation from user's perspective; and what is the method that will suffice to realizing the first question. These questions are pivotal considering the argument of Mandl (2008) that users are often excluded from IR system evaluation exercises. Thus, this study seeks to present a model that will serve the purpose of assessing IR system, from users' perspective by formulating a user-centric evaluative model. Both model's testing and verification were carried out as presented in this study.

4. The Empirical Model

The issue of interactivity, which is multidimensional in any user-system interaction, often presents a constraint of how to model the user in respect of their use of end-user applications. The constraint is that end-users bring their own knowledge, experience and searching abilities to bear during interactive search sessions (Dunlop 2000). Furthermore, user modeling often presents relationships that a similar and depending on the sample size the relationship to be modeled could be amazingly large. For a study that requires multivariate data, which includes for instance the presentation of N decision variables for assessment to an audience of a sample size M; the challenge this presents is the handling of linear equations of order (N x M) dimension. As a consequence, the matrix experimental model is presented in equation (i). Similar approach has been used in user-related studies (Heimeriks 2004; Arekete & Akinyokun 2007; Akinyokun & Adejo 2009).

$$Z_p, = \sum_{i=1}^{N} a_{p,i}x_i; \quad \text{with } p = 1,2, \ldots, M \qquad \ldots\ldots\ldots\ldots \text{(i)}$$

Where;

Z_p = *the* p*th respondent's (assessor's)observation of the system based on decision variable* x_i *and* $a_{p,i}$*;*

x_i = *the* i*th reponse of the* p*th assessor using the assessment of the* i*th decision variable (item) by the* p*th assessor, and*

$a_{p,i}$ = *the* p*th assessor (respondent) with* i*th decision variable.*

With this understanding the mathematical model in equation (1) is expressed as a matrix of the form demonstrated in equation (ii).

$$\begin{bmatrix} Z_1 \\ Z_2 \\ Z_3 \\ . \\ . \\ . \\ Z_M \end{bmatrix} = \begin{pmatrix} a_{1,1}x_1 + a_{1,2}x_2 + & \ldots & a_{1,N}x_N \\ a_{2,1}x_1 + a_{2,2}x_2 + & \ldots & a_{2,N}x_N \\ a_{3,1}x_1 + a_{3,2}x_2 + & \ldots & a_{3,N}x_N \\ . \quad . & & . \\ . \quad . & & . \\ . \quad . & & . \\ a_{M,1}x_1 + a_{M,2}x_2 + & \ldots & a_{M,N}x_N \end{pmatrix} \qquad \ldots\ldots\ldots\ldots \text{(ii)}$$

The matrix of order (N x M), described in equation (i) and (ii) was used to model the relationships between the assessors and the variables (items) presented to elicit their response (observation or judgment) of the system under review. This is underpinned by the fact that each of the respondents have interacted with one or more search engines for a period of time, which was also captured using the demographic aspect of this study.

5. Materials and Methods

A 17-variable item was used for the study for a sample size of about 250. The questionnaire method was used to elicit the data used for the study. All of these variables (items) are from previously validated scales as done in related work such as that of (Wu & Diane 1999; Nauman *et al.* 2009; Akhigbe *et al.* 2011a). The factor analytic method was therefore optimized with this survey technique to achieve the purpose of the study, which was earlier mentioned. Therefore, with respect to the data used in this study, N = the number of decision variables or questions presented to each user of the system; and M= the total number of users (respondents), who participated in the assessment exercise. For this study, while N=17, M=250. As a result the original dataset was used to construct a (17 x 250) matrix that contains 15 mechanisms (items or variables) put together for the 250 respondents (users), who have used any one or more search engines for one retrieval task or the other.

5.1 Generated Statistics

The statistics generated resulted by subjecting the mathematical model in equation (1), which is demonstrated in equation (2) to the Factor Analytic (FA) technique using the principal components approach. The statistics are: the communality value statistics, the eigenvalue statistics (ES) and the factor loadings (FLs). Others include Composite reliability (CR), Average variance extracted (AVE) and so on that was used to demonstrate the proposed model's testing and verification for reliability and validity. The FA approach was adopted due to its ability to perform data reduction. As a data reduction technique (Suhr 2005; 2006); FA was employed to also handle the multidimensional and multivariate nature of the relationship modeled. Moreover, in line with the effort of (Akinyokun & Adejo 2009), the primary goal was to obtain some factors each of which would load on some decision variables. This was with a view to suggesting them for use in the evaluation of IR system, without loosing focus on the user-centeredness which forms the basic philosophy of the study.

5.2 The purpose of the generated statistics

The communality value statistics was used to; first observed which of the items would contribute less to the supposed cooperative effort of each items towards realizing any of the proposed factors. After which if any is less than the recommended threshold point of >= 0.4; they will be dropped. Also, in order to evaluate the contributions of each factor (component) the eigenvalue statistics were generated. They were used to show the possible number of factors that would result from the items at the end of the FA process. The component matrix statistics was used to present both the initial FLs and the extracted ones. This is the degree of generalization found between each item (decision variable) and each factor. Therefore, since they are associated with a specific item, it was generated to show the correlation between the factor and the standard score of the variable. In (Arekete & Akinyokun 2007), it was reported that the farther away a factor loading is from zero in the positive direction, the more one can conclude the contribution of an item to a factor. The component matrix produced was rotated using equamax for the purpose of establishing a high correlation between items (respondent's responses) and measures. The scores of each item were used to determine the final factor score used to formulate the prior (hypothesized) factor structure (FS) or experimental model. Therefore, with the FS in place, it was possible to eliminate factors that fail to leave up to the rule of parsimony. That is factors with only one item (decision variable) were dropped. This practice is standard and recommended in literature (Ong *et al.* 2009; Nauman *et al.* 2009).

6. Data Collection

Considering the coverage of the search engine, especially as a web based phenomenon, both the online and hardcopy questionnaire was administered. In line with (Wu *et al.* 2008; Nauman *et al.* 2009), a number of prior related studies were reviewed to ensure that a comprehensive list of relevant items and measures were included. As a result, all the items and measures were taken from previously validated instruments. And to ensure that the final instrument, which was administered, would serve the purpose, a pilot study was necessary to further confirm this. The Cronbach alpha test was carried out on the data from the pilot study, using the approach in (Gliem & Gliem 2003; Sun *et al.* 2007). The result was positive, since all the items scored from 0.70 and above, as recommended in (George & Mallery 2003). A 5-point likert scale ranging from 1 (strongly agree) to 5 (strongly disagree) was used to present the items (closed questions) to the users of the system. This was with a view to comprehensively rate their experience with the system, base on their interaction with it. Also, data were collected between 2010 and 2011.

6.1 Data Analysis and Result

The questionnaire which is presented in Appendix A below exhibits 17 decision variables intended to elicit user's experience during previous series of interactions with search engines. The questionnaire required that the respondents rate each of the decision variables using the 5-point Likert scale mentioned above. Thereafter, the final data were subjected to factor analysis using the method of principal components analysis, with the Statistical Package for Social Sciences (SPSS) providing the leverage needed for the analysis as in (Morrison 1983; Akinyokun 1993; Akinyokun & Chiemeke 2006; Angaye *et al.* 2008; Akinyokun & Adejo 2009; Akhigbe *et al.* 2011a).

6.1.1First result

The first result to be presented is the result of communality values. These values as presented in Table 1 show that each of the items (itm1 to itm17) was okay for the next statistical regour in the use of exploratory factor analysis (EFA). This is because all of the item score for items (itm1 to itm17) presented are well above the recommended threshold point of >= 0.4. Also, with this, it is obvious that the items if presented for FA test using the exploratory factor analysis technique, would yield reasonable result since the least score (.609 of itm8) is far above the recommended cut of point of 0.40.

6.1.2 Second result

The second result is the result of eigenvalue statistics, which is presented in Table 2. The result as presented in Table 2 reveals that about 4 factors are likely to result from the 17 items presented for the study. This means that each of the 4 expected factors will have any of the 17 items as their underlying factor structure. The result presented also reveals the percentage contribution of each factor to the expected empirical model. The eigenvalues of each factor was estimated and generated using equation (iii). Thus the eigenvalue of jth factor denoted by evj was calculated by:

$$ev_j = \sum_{i=1}^{17} X^2_{i,j}$$

Where;

$i = 1, 2, 3, 4, \ldots\ldots 17$;

$j = 1, 2, 3, \ldots\ldots., 4$ and

X^2i,j represents the factor loading of jth factor on ith decision variable.

The result shown in Table 2 was also used to indicate how well each of the extracted factors fits the data used for the study.

6.1.3 Third result

The third result is the result of FLs presented in Table 3. The result is a summary of both the initial FLs and the extracted (rotated) FLs using equamax. This result was used to formulate the hypothesized factor structure, using each of the emerged factors and their corresponding underlying items. In Table 3, due to the criteria of parsimony, i1(1-2) and i4(9-10) was dropped. Thus i2(3-4), i3(5-8), i5(11-13), i6(14-17) are the underlying structure of the factors RS, IQ , UT and SQ respectively. However, two of the items of the factor structure of factor SQ were below the threshold point of > 0.5 as shown in Table 3. As a result the two items (i14 and i15) were dropped, hence i(16-17) which scaled through was retained and became the underlying factor structure of the factor SQ.

6.1.4 Fourth result

The fourth result is the result showing the reliability and initial validity of the model based on each of the factors, which formed the model. This result is presented in Table 4. In the Table 4, the column Par contains the resultant factors (parameters/measures) being suggested, which emerged from the 17 items presented for the study. While RS, IQ and UT is Reliability of system, Information quality and User’s technical capabilities respectively, SQ is Service quality.

6.1.6 Fifth result

The fifth result arrived at is the result that reveals the overall validity of the model. The validity was estimated using the structural equation modeling technique and compared with the standard value recommended in literature (Hair *et al.* 2005; Wu *et al.* 2008). This result is as presented in Table 5.

7. The Proposed model in diagram

Finally, the proposed model is presented in Figure 1 below. The model is the diagrammatically represented with its components: factors and the corresponding FLs of each of the items, thus revealing the underlying strength/weakness of each of the items of the factor structure. The model as it is made of four (4) factors (measures) and 11 items.

8. Conclusion

The purpose of this study is to contribute to IR system evaluation from end-users perspective, which has not received as much attention as necessary as possible. Hence, the relevance of the study is underscored when compared to the well known and used system perspective of the IR system evaluation. As a result an empirical model, with its components (measures) and the method experimented upon to achieve it is proposed. The model is founded on data resulting from user's assessment of any three search engines. Part of the assumption for this study concerns the user-system interactive approach. Those who participated in offering their judgment (opinion) of the system would have interacted with the system; either on a daily, weekly, monthly or yearly basis as the case may be. Also, at least 5 to 10 users of the system were assumed to have responded to at least one item, as recommended in literature (Suhr 2006; Treiblmaier & Filzmoser 2010).

The result presented demonstrated that the method employed for this study was adequate for use in suggesting the parameters presented. It also demonstrated that the model is reliable; that is when it (particularly the parameters that formed the model) is reused it will retain its value. Also, the result of the model's validity showed that any time it is reused in the future; the values of Comparative Fit Index (CFI), Root Mean Square Residual (RMSR) and Root Mean Square Error of Approximation (RMSEA) will not changed. This is shown in Table 5. As a result it is expected that based on the degree of statistical regour, and the confidence demonstrated by the measure of reliability and validity of the model reported; it could also be used to evaluate other end –use applications in information system. Obviously, by so doing the user's own knowledge, experience and searching abilities could be brought to bear, and would contribute immensely to the overall improvement of the system. This study is not without a limitation. The need to use other extraction method (since the one used in this study is equamax) to experiment with, using more items and larger random sample size is y important. However, this is left for future work.

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Notes

Table1: Showing the Communality value statistics

S/N	IC	IE	E	S/N	IC	IE	E
1	itm1	1	.617	10	itm10	1	.710
2	itm2	1	.673	11	itm11	1	.706
3	itm3	1	.625	12	itm12	1	.755

4	itm4	1	.764	13	itm13	1	.769
5	itm5	1	.763	14	itm14	1	.758
6	itm6	1	.524	15	itm15	1	.789
7	itm7	1	.631	16	itm16	1	.654
8	itm8	1	.609	17	itm17	1	.698
9	itm9	1	.702				

*IC (**Item code**), *IE (**Initial estimate**), *E (**Extraction**)

Table 2: Showing Eigenvalue statistics

Co	**ESSL**		
	T	**% of V.**	**Cu. %**
1	14.926	39.278	39.278
2	3.146	8.280	47.558
3	2.226	5.858	53.416
4	1.799	4.733	58.149

***Extraction Method: Principal Component Analysis,** *Co (**component**), *ESSL (**Extraction Sums of Squared Loadings**), * T (**Total**), *V (**Variance**), *Cu (**Cumulative**)

Table 3: Showing the summary of Factor loadings

IC	**FLs (> 0.5)**
i1(1-2)*	*; .558
i2(3-4)	.742; .777
i3(5-8)	.595; .670; .651; .604
i4(9-10)*	.595; *
i5(11-13)	.584; .596; .871
i6(14-17)	*; *; .728; .731

*IC (**Item code**), *FLs (**Factor Loadings**), *Cut of point (>**0.5**)

Table 4: Showing the result of the model's Reliability and initial validity base on each factor

Par	RS	IQ	UT	SQ
CR(> 0.6)	0.83	0.78	0.70	0.67
AVE (>0.5)	0.81	0.68	0.73	0.76

*Par (**Parameters**), *CR (**Composite reliability**),

*AVE (**Average variance extracted**)

Table 5: Showing the result of the overall validity of the model, using the goodness-of-fit statistics

G.Par.	X^2/df	GFI	NFI	NNFI	CFI	RMSR	RMSEA
SRViL	<=3.00	>=0.9	>=0.9	>=0.9	>=0.9	<=0.05	<=0.08
MR	2.51	0.091	0.097	0.093	0.89	0.046	0.075

G.Par **(Goodness of Fit Indices Parameters);** SRViL **(Standard Recommended Value in Literature)** and VMR**(Values of Model's Reliability);** x^2/df **(Chi square/degree of freedom),** GFI **(Goodness of fit index),** NFI **(Normed Fit Index),** NNFI **(Non-Normed Fit Index),** CFI **(Comparative Fit Index),** RMSR **(Root Mean Square Residual)** and RMSEA **(Root Mean Square Error of Approximation)**

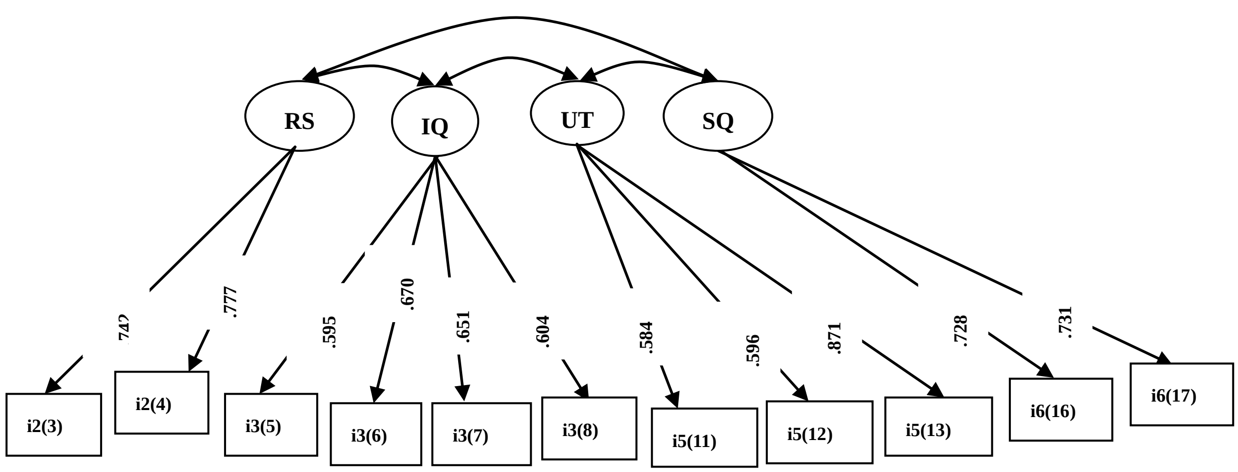

Figure1: The Empirical model from user's perspective