An Evaluative Model for Information Retrieval System Evaluation: A User-centered Approach

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Abstract **-** The key technology for knowledge management that guarantees access to large corpora of both structured and unstructured data is Information retrieval (IR) Systems. The ones commonly used on an everyday basis are search engines. This study developed and validated an evaluative model from user's perspective meant to assess these systems using the user-centered approach. Items used and validated in other related studies were used to elicit responses from over 250 users. The reliability and validity of the measurement instrument (MI) was demonstrated using statistics such as internal consistency, composite reliability and convergent validity. After assessing the reliability and validity of the MI, the resultant evaluative model was estimated for goodness-of-fit using the structural equation modeling (SEM) technique. Results confirmed that the suggested model is valid and will be useful to researchers who wish to use it. Thus, this study suggests both the parameters and methods employed to formulate the model for use in user-centered studies for the evaluation of IR system. Both the evaluative model, factor analytic methods of data analysis, could be used to understand and present more factors (parameters) that will be usable for IR system evaluation using the user-centered approach.

Keywords - Goodness-of-fit, corpora, Information retrieval (systems), user-oriented paradigm, structured and unstructured data

I. INTRODUCTION

The key technology for knowledge management that guarantees access to large corpora of both structured and unstructured data is Information retrieval (IR). This technology is also the basic technology behind web search engines, question and answering systems, and recently it has been introduced in the implementation of natural language processing systems [1]. It has become an everyday technology for many web users. Better put, IR is the storage and representation of knowledge and the retrieval of information relevant to a specific user problem [2]. Systems with these abilities are often known as Information retrieval (IR) systems. These systems allow millions of users of the web and other applications (in which they are embedded) to express their information needs as queries, with the expectation of feedback as response to their queries. According to [2], user's queries are compared to document representations which were extracted during an indexing phase, with the most similar documents presented to users who are expected to evaluate their relevance with respect to their information needs and problems.

The term "information retrieval" was first used by a researcher named Calvin Mooers in 1951. The name for the processes or methods whereby a prospective user of information is able to convert his need for information into an actual list of citations to documents in storages containing information useful to him is information retrieval. It has also been defined broadly as the process of finding information satisfying a user's need [3], [4]. The term cut across both the intellectual aspects of the description of information and its specification for search, and also whatever systems, techniques or machines that are employed to carry out the operation of searching for relevant information that meets user's information need [5]. The goal of an information retrieval system (IRS) is to locate relevant documents in response to a user's query [4]. Nevertheless, information retrieval (IR) systems and their evaluation have increased in importance. It has become a very active area of research and development with continued information explosion. This has been fueled by factors such as: The emergence of the internet; new and innovative digital library initiatives; the

volume of web pages in the World Wide Web and the ever increasing information need of users globally [6] and [4]. As such the need to evaluate this system holistically cannot be overlooked.

Two major methods in literature have been suggested for the evaluation of IR systems. The first one, which is more widely used, is the system-centered methods. Several results abound as a result of this method, having being used extensively by employing well parameters like: Precision and recall [2]. The second method is the user-centered approach. According to Saracevic [5], "one can conceive two ways of evaluating IR, namely system evaluation; user evaluation (evaluating the system) from a user point of view. Although [7], was the first to identify these two levels; other researchers [6], [3], and [8] have also recognized these levels. Whereas much work has been done using the system-centered paradigm, very few have been achieved using the user-centered method [5], [6], [9], [1]. The result of this is the existence of already established parameters (metrics) for applying the system-centered approach to evaluate IR system [6], [10], [11], [12] but there is dearth of parameters for applying the user-centered method.

This paper seeks to suggest an evaluative model from user's perspective using the user-centered paradigm. As a result the model's parameters, method of realizing them as well as testing their suitability for use from user's perspective is proposed. The results from this study are both generalizable and thoroughly tested empirically using real life data that were elicited from real life audience who have used any one or more IR system. Section II is a discourse on the main aim and objectives of the study; while section III, IV, V and VI considers related study, the research methodology of the study, data analysis and results and the proposed model respectively. Finally the paper ends with section VII containing the conclusion and VIII the references.

II. AIM AND OBJECTIVES OF STUDY

The system-centered approach has failed to address issues from user's perspective. This has brought about challenges in usable and reliable parameters for use in employing the user-centered paradigm in the evaluation of Information retrieval (IR) system, hence this study. As a result, the overall aim of this paper is to achieve an evaluative model, and thus suggest both parameters and empirical method for use in the user-centered paradigm. In order to achieve this aim, the following specific objectives were set out and pursued:

(i) To identify and assess new parameters from users' perspective for use in the evaluation of IR system;
(ii) formulate a user-centered evaluative model resulting from identified parameters; and
(iii) test the reliability and validity of the model.

III. RELATED STUDY

First, the measures of recall and precision have been used to measure the performance of IR system in terms of relevance in the field of IR with much acknowledgement [13], [6], [10], [11], [12]. Several researches such as: [14], [15], [16], [17], [4], and [2], have criticized the continuous use of these parameters. While some questioned their usefulness, others argue that although they are good metrics suitable for the system-centered approach to evaluating IRSs, they cannot be used to measure the degree of usability and success of IRSs, especially from user's perspective using the user-centered paradigm. Also [16], [17]. [18], [19] and [20] in their work claimed that the measures did not incorporate factors external to IRSs, thus affirming the need for a shift in IRS evaluation paradigm.

[9] in his critique referred to this as the challenge of how to move IR research beyond the limited and inherently non-interactive models of IR. Although this is still the focus of IR researchers, he emphasized the development of IR evaluative models. These models he said should incorporate the user as an active participant in the evaluation of IR system. Nevertheless, [19] did not suggest any related model or parameters for achieving the model he suggested. [1] claimed that most evaluation models focus on system-centered evaluation, while the user-centered evaluation has continued to attract less attention. Thus to realize a usable IR system, there was the need to achieve a performance level that satisfies the majority of users. Questions such as: How do individual users evaluate the success of an IR system, and what factors influence an individual user's evaluation of IR system success is, were answered in order to meet their goal. As a result some existing user-centered parameters were assessed using the factor analytic method. As argued by [2], users who were often assumed as abstraction in the system-centered approach were incorporated the user, thus factors (parameters) needed for the evaluation of the system, was identified from users perspective.

In the work of [6], the effort reported was about the integration or fusion of both the system-centered and the user-centered paradigm. The framework proposed was for synthesizing these approaches. The proposed framework was expected to assist in the design and synthesis of evaluation results across different systems,

situations and contexts. The major challenge with the model was that it was not applied to a specific real life scenario. Thus the model was not subjected to any empirical analysis and testing and was left for future work.

[21] acknowledged the fact that there exists a well-known gap between the systems-centered IR and cognitive IR approaches (user-centered IR). These approaches were found to be quite different. The aim of the article was to discuss and analyze both approaches, with respect to models, hypotheses, laws and theories, study designs and contributions as it concerns IR system evaluation and design. However, no model, parameters as well as methods were suggested nor empirically tested. [12] proposed an Ontology based IR (ObIR) system. The spur was to introduce ontology concept into IR systems, as a way of ensuring better information quality. This effort yielded good result, but introduced another challenge that required a more holistic approach to evaluating the model. This approach to ObIR's evaluation provided a basis for paradigm synthesis (the system-centered and the user-centered paradigm). A major challenge with the final work was that the model realized ObIR's evaluation was not empirically tested.

How results from evaluation exercise especially from system-centered approach relate to user satisfaction was raised by [2]. This work reported comprehensively recent developments in IRS evaluation. In summary, [2] concluded that although many novel retrieval measures have been developed in the past few years, nevertheless, the classic measures such as precision and recall, and their variants are still being widely used. But there is a consensus about the fact that new measures (if suggested or available) might reveal something important that is not covered by recall and precision. Thus, evaluative measures from users' perspective were needed to be re-considered, and suggested. The work of [2], was a critique and did not shoe any empirical evidence of a model suggested to back claim. Finally, the critique and work of [22], [23], [1], [24], [25] and [26] provided enough leverage and useful inspiration upon which this study derives from.

IV. RESEARCH METHODOLOGY

A Scale items and Measures

All the items (both the ones eliminated and retained) for each factor (parameters) were taken from the previously validated instruments as done in related work such as that of [23] and [[28]. These items were measured on a five point likert scale, ranging from 1 (strongly agree) to 5 (strongly disagree). While the scales: Content (C), accuracy (A) and ease-of-use (E) were adopted from [27]; usefulness (U) was from [1]. Their adaptation was base on their relevance to this study as related studies and because their construction followed the guidelines of scale development procedures as proposed by [22]. Before this, a thorough literature review within the body of information system, which includes that of information retrieval, was conducted. The literature search resulted in the choice of several multiple items (multi-items) as earlier mentioned with their constructs (parameters). Although the constructs of the items were known at this stage, it did not matter, since they were yet to under go series of statistical rigours. This is with a view to retaining and suggesting them if certified okay using de facto standards. In order to purify the scale a pilot study was conducted. Since, each of the items were used in previously standardized and validated scales, this was to ensure that the scale will measure exactly what it is meant for. Result of the study showed that he Cronbach alpha coefficient (CAC) range from 0.70 and above. This confirms that the scale is okay for the exercise. This approach is in accordance with that of [1], [28] and [29]. The CAC result in V(C) below is the one from the remaining items based on their corresponding parameters after the rest were eliminated based on parsimony and inability of them to meet cut-off (threshold) point.

B Data Collection and Statistical analysis

In accordance with the aim of this study, first as a user-oriented study, users' were identified as the main actors in the evaluation process. Secondly, a survey method was employed for data collection as done in the work of [29], [23], [1] and [26] from those who have used one or more search engines (IR systems). Data used in this study came from the administration of the questionnaire instrument from within and outside Nigeria. While the online survey method was used to elicit data from users outside the country, hardcopies of the same survey instrument was used to get data from within the country. The total number of valid responses used was about 250, and was okay as suggested by [30, 31]. In order to meet with the specific objectives of the study the factor analytic method was employed for data analysis. With the method the items meant to initiate the suggestion of parameters were achieved since the method provided valid statistical rigorous process required for thorough delivery of measures. To describe the main features of users who participated in the study, descriptive statistics was used on the respondents' characteristics data. Structural equation modeling (SEM) was used to test the fit of the proposed theoretical model. The proposed evaluative model was estimated using confirmatory factor analysis (CFA) to test whether the proposed constructs (parameters) possessed sufficient validation and

reliability. All the needed statistical analysis was performed using the SPSS statistical package together with the LISRELS software.

V. DATA ANALYSIS AND RESULT

In this section, both data analysis and results are given. In order to achieve this, the following statistics: Descriptive, eigenvalue , factor loadings along with reliability and validity statistics, internal consistency of factors and SEM statistics were generated as discussed in the following subsection.

A Descriptive Statistics

The characteristics of the respondents are as presented in Table 1 below. The most respondents from the table were between ages 36-45 years old, with the male counterpart being the one who use the system the most. Furthermore, workers use the system the most, followed by student and lecturers with the same frequency of usage. Also, those who use the system for research were the least in terms of frequency of use.

TABLE 1: RESPONDENTS PROFILE

Age		
Age range (yrs)	**Frequency**	**Percentage**
16-25	43.35	17.34
26-35	66.90	26.76
36-45	120.07	48.0
46-55	11.81	4.70
55 and above	7.87	3.2
Total	250	100.0
Gender		
Sex	**Frequency**	**Percentage**
Male	194.88	78.0
Female	55.12	22.0
Total	250	100.0
Status		
Profile distribution	**Frequency**	**Percentage**
Student	55.12	22.0
Worker	104.33	41.7
Lecturer	55.12	22.0
Researcher	35.43	14.2
Total	250	100.0

B Eigenvalue statistics

The purpose of this statistics is to establish the degree (amount) of variance explained by each parameter [31]. This was with a view to reveal how each of the proposed items explain each of the intended parameters, and thus show the suitability of the parameters for the proposed model formulation. The result was also intended to show the degree of extraneous items needed to make up for the remaining contribitions (usually assumed in percentage) necessary to make up the sum total of each parameter (factor). This is in agreement with the standard described by [32] and also applied in the work of [1], [33] and [34]. This statistics was used to emperically assess the parameters identified from the standpoint of the items that was used to present them to users for appraisal. Thus the result obtaind are as presented in table 2 below. The result showed that all four parameters got a score of 1.0 and above, which is very good for the study. This is in agreement with other study like [1], [33], [34] and [32].

TABLE 2: EIGENVALUES

Components	Total	% of Variance	Cumulative %
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

C Factor loadings with Relaibility and Validity Measures ,and Iinternal consistencyof factos

Having assessed the parameters identified using the eigenvalue statistics as presented in section B above, it is therefore important to further scrutinize them. The purpose is to be sure of their suitability for the proposed model's formulation, which is one of the specific aims of this paper. To achieve this factor loading statistics was generated using the exploratory factor analytic (EFA) technique. Since there was no need for hypothesis testing due to the goal of the paper, which does not include the influence of a factor on others or vice versa, only reliability and validity of measures (parameters or factors using their items) were attended to. To this end the measurement items in the questionnaire used were assessed both for content and construct reliability, and validity. The results of these tests were to show the extent of the unidimensionality, reliability and convergent validity provided as evidence of the internal and external validity of the measurement instrument and scales. Also, the internal consistency of the factors (parameters) and their items were assessed by Cronbach's alpha (α). The purpose was to estimate the extent to which multiple items (indicators) of a latent variable belong together. According to [26] the expected evaluative model was estimated using the confirmatory factor analytic (CFA) technique to test whether the proposed parameters possessed sufficient validation and reliability. All the cut-off values used are as shown in the table 3 below. Thus from the result presented all the constructs (measures showed a reasonable level of reliability and validity. This approach is in accordance with that of [26]. Inferential statistics such as SPSS and LISREL were used for all the analysis in the study. They were used to obtaine the expected result for Cronbach's alpha (α), Composite reliability and average variance extracted (AVE) were estimated using the following equations:

$$\alpha = \frac{k\bar{r}}{1+(k-1)\bar{r}},$$

where $\bar{r}$ *is the mean of the* $k(k-1)/2$ *nonredundant correlation coefficients* ..... (i)

$$Cr = \frac{(\sum factor\ loading)^2}{(\sum factor\ loading)^2 + \sum measurement\ error} \quad \text{.....(ii)}$$

$$AVE = \frac{\sum (factor\ loading)^2}{\sum (factor\ loading)^2 + \sum measurement\ error} \quad \text{.....(iii)}$$

While equation (i) is from [35], (ii) and (iii) is from [26], the table 3 below contains a summary of the results from these estimations. Also, all of the statistics presented using the table has been used in related studies [29], [23], [1] and [26] to show reliability and validity.

Table 3: Factor loadings and other values

Constructs (Measures)	Items	FL >= 0.50	CV values Using (AVE) >= 0.50	Fr values Using Cr >= 0.70	IC Values Using CA (α) >= 0.70
Content	C(1-4)	.502; .682; .658; .773	0.65	0.71	0.77
Accuracy	A(1-2)	.842; .585	0.71	0.55	0.85
Ease of use	E(1-6)	.699; .749; .642; .706; .756; .692	0.76	0.72	0.71
Usefulness	U(1-5)	752; .793; .879; .846; .840	0.63	0.80	0.91

Convergent validity (CV), Factor reliability (Fr), Internal consistency (IC), Average variance extracted (AVE), Cronbach alpha (CA) and Composite reliability (Cr)

VI. THE PROPOSED MODEL

The model in question is being referred to as the evaluative model in this paper. The model with the parameters and their items are presented in figure 6 below.

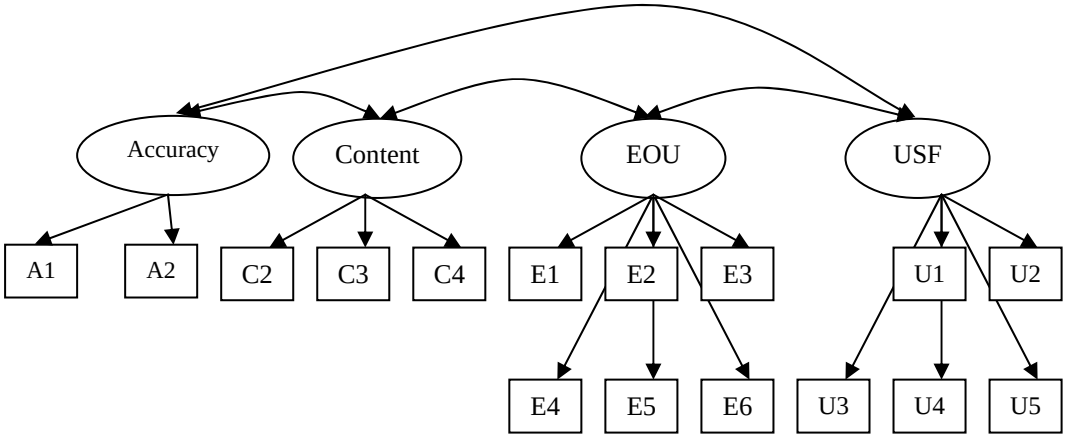

Figure 6. The Evaluatuve model

The CFA, using the structural equation modeling (SEM) technique was used according to the modification indices provided as a result of the Inferential statistics used the overall fit model of the evaluative model was estimated to ensure a good data fit. As practiced in [26], and proposed by [36], a variety of fit indices were assessed to identify this model's goodness-of-fit. The summary of results using the fit indices (statistics) is presented in table 4 below.

TABLE 4: MODEL FIT SUMMARY FOR EVALUATIVE MODEL

Fit Indices	recommended Value (SRV)	Evaluative model
x^2/df	<= 3.00	2.65
GFI	>= 0.9	0.94
NFI	>= 0.9	0.097
NNFI	>= 0.9	0.093
CFI	>= 0.9	0.089
RMSR	<= 0.05	0.046
RMSEA	<= 0.08	0.066

χ2//df, Goodness-of-fit index (GFI), Comparative fit index (CFI), Root mean squared residual (RMSR), Root mean square error of approximation (RMSEA), Normed fit index (NFI), Non-normed fit index (NNFI) and Standard recommended value (SRV)

VII. CONCLUSION

The present study resulted in the identification of items from validated instruments, which were assessed as the result presented showed. Also, the evaluative model was formulated as one of the objective of this study using the parameters identified following satisfactory statistical rigour. The proposed model was as well tested and validated using SEM. The nature of the results presented in the study in terms of validity is a function of the authenticity of the parameters identified and the method used. Thus both parameters and method are suggested for use in the evaluation of IR system from user's perspective using the user-centered approach. Similar results have been demonstrated in several other related studies [1], [23], [26], [29], [22], [24], thus authenticating both the validity of parameters and method (the factor analytic method) suggested.

The results of this study have implications, which are relevant to different stakeholders. The result of the research confirms the benefit, which can be attained with more developmental studies along the borders

presented by the parameters identified. Thus if implicated in the design of IR systems; the system will be more useful and better accepted by a greater audience of users.

This study has limitations: First a large amount of data is needed in order to ensure better result. Most of the respondent only had used just one search engine, and thus using that experience to evaluate IR system is a weakness. Also, more items are needed so as to provide the needed leverage for more parameters to be established for user-centered studies in IR system evaluation from user's perspective. With this weakness, comes sufficient future work, since attempting to solve them will obvious provide interesting challenges.

According to [26], we cannot but also think that there are still a lot of constructs (parameters based on items), which are related to the user; to IR system technology; and to the service domain characteristics where it is useful. As a result, the task of finding and evaluating them is certainly a major commitment for the future.

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