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Review Article
Design of a QoS-based Framework for Service Ranking and Selection in Cloud E-marketplaces

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Abstract
In most existing commercial cloud e-marketplaces, finding a suitable cloud service to perform user's objectives can be cognitively demanding and potentially affects the user satisfaction of both the process and outcome of decision making. Most existing cloud selection techniques have not sufficiently addressed the problem of service choice overload in a manner, that provides means that elicits subjective user preferences. Besides, only a few of these techniques suffice in situations where there are a large number of services to be evaluated and the results are presented in textual formats, either in a list or tables, which does not provide any means of comparison of results returned. Based on a comparative review of existing service selection techniques, a set of requirements was identified to guide the design of cloud service selection framework that would suffice in a cloud e-marketplace context. A cloud service selection framework was formulated that encapsulates the set of requirements. The increase in the number of available services on the e-marketplace leaves the users in the dilemma of which service to select, particularly when the services perform equivalent functionalities and may only differ with respect to their quality of service (QoS) attributes. The proposed framework is a viable proposition for the reduction service choice overload in cloud service e-marketplaces.

Key words: Cloud computing, cloud service selection, cloud service e-marketplace, fuzzy set theory, quality of service, visualisation

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INTRODUCTION

Cloud computing has recently emerged as a new paradigm for hosting and delivering services over the internet[1,2]. A number of service providers now offer an assortment of IT capabilities through the cloud. The maturity of cloud computing will be fast-tracked by the commoditization of cloud services through the cloud service e-marketplace where these services will be traded[3-8]. The popularity of such cloud service e-marketplaces will be similar to Amazon (Amazon.com) or Alibaba (Alibaba.com), such that a large number of services from multiple providers will be available in the marketplace for users to select from. Typical examples of an e-marketplace include Salesforce's AppExchange[9], Oracle e-marketplace, Microsoft Azure Marketplace, etc. The proliferation of services from multiple cloud service providers tends to culminate in an exponential increase in the number of service options available to users.

The increase in the number of available services on the e-marketplace leaves the users in the dilemma of which service to select, particularly when the services perform equivalent functionalities and may only differ with respect to their quality of service (QoS) attributes. In most existing commercial cloud e-marketplaces, finding a suitable cloud service to perform user's objectives can be cognitively demanding and potentially affects the user satisfaction of both the process and outcome of decision making[4]. The difficulties experienced when selecting from an assortment of services can be referred to as service choice overload (or service over choice), i.e., the more the number of options, the lesser the motivation to choose or the lesser the satisfaction with the final choice[10]. Existing cloud service e-marketplaces are characterised by service choice overload. Currently, such platform only allows a keyword-based search that does not consider subjectivity in the user QoS requirements and lists the search results as a list of icons that are arranged in no particular order. In addition, the presentation of the search results on existing e-marketplaces burdens the users with the responsibility of analysing each service one after the other to determine the one that best matches technical requirements and meets business needs.

Besides, service choice overload can be minimised on cloud e-marketplaces by employing low cognitive demand decision support mechanisms. These mechanisms will support the elicitation of the user's QoS requirements in a way that also takes into considerations the vagueness often associated with how human express themselves. The mechanisms should also have the ability to convert the requirements into a search query that is used to perform a QoS-based evaluation of each cloud service. Afterwards, the mechanism should employ some type of visualisation heuristics to explore the result of the query, while allowing a means for minor adjustments to initial query[4,11]. It is believed that such decision support would lead to higher user satisfaction of process and outcome (choice of service) of decision making[12].

A number of cloud service selection techniques have been proposed in the literature. However, most of these techniques have not sufficiently addressed the problem of service choice overload in a manner that provide means that elicits user preferences via an intuitive user interface that captures the vagueness inherent in human expressions. Also, most hardly consider both dimensions of QoS preferences, which are the user's priority weights and actual desired values for each QoS attributes. Besides, only a few of these techniques suffice in situations where there are a large number of services to be evaluated and the results are presented in textual formats, either in a list or tables, which does not provide any means of comparison of results returned. These drawbacks contribute to increase service choice overload, while increasing the cognitive load on the user and thereby, impacting negatively on the overall user experience of e-marketplaces[13,14]. Hence, there is a need for a framework for service selection in e-marketplaces.

The main aim of this study is to propose a framework that will guide the design of cloud service selection techniques suitable for cloud e-marketplaces. First, a comparative review was performed on existing service selection techniques and a set of requirements was identified that would guide the design of cloud service selection framework that would suffice in a cloud e-marketplace context. Based on the proposed requirements, a cloud service selection framework was introduced that encapsulates the set of requirements and argued the viability of the proposed framework.

BACKGROUND

The future of cloud computing and cloud services would be fast-tracked by successful partnerships and collaborations as multiple service providers tie their services together. This provides an environment where anything/everything as services are delivered to meet business needs[15]. Such moves are already being driven by the advancements in service orientation and virtualization[16]. As more and more service providers enter the cloud landscape, there is a need for a one-stop shop for trading cloud services. Presented next include an overview of the cloud service e-marketplace, the QoS model for cloud service selection and the concept of service choice overload.

Customer A		
	QoS order of preference	QoS aspiration
	Eco-friendliness	High
	Security	Medium
	Availability	High (>90%)
	Cost	Around $25/month

Customer B		
	QoS order of preference	QoS aspiration
	Cost	Less than $50/month
	Eco-friendliness	High
	Availability	Medium (around 60%)
	Security	Medium

Fig. 1: QoS Preference and aspiration for two users: User A rates eco-friendliness as highest priority irrespective of the cost. User B is more budget conscious and is willing to compromise security for lower cost

Cloud service e-marketplaces: The cloud e-marketplace extends the concept of an electronic e-marketplace, which is a platform where the demand and supply for certain products or services are fulfilled using information and communication technologies[4,17]. On this platform, service providers register their services based on their QoS dimensions, while users can discover, consume and pay for services that satisfy their QoS preferences[3-6,11,12,18]. The vision of an e-marketplace for cloud services is similar to Amazon.com, in which multiple providers showcase a variety of services and an e-marketplace mechanism regulates the interactions and transactions between the providers, users and other participants[12]. The e-marketplace provides a unified view of all available services and is a single point of access to the available services[11]. Furthermore, the e-marketplace also integrates a mechanism for managing pricing, revenue sharing, service advertisement and promotion and billing[4,11]. Examples of commercial cloud e-marketplaces include Windows Azure Marketplace, Amazon Web Service, Google Apps Marketplace, App Store, AppExchange android Market, SuiteApp.com and Zoho[4].

QoS-driven cloud services selection: Apart from the capabilities they provide, cloud services possess non-functional or quality attributes classified into technical concerns- reliability, response time, cost, availability and business concerns-security, usability, eco-friendliness, geographical location and political dimensions etc.[11,19,20]. The measure of these attributes in service usage scenarios, as perceived by the user, is described as quality-of-service (QoS), therefore, QoS attributes are major determinants in the selection of cloud selection[21,22]. The QoS information of cloud services is usually obtained through objective and/or subjective assessments. Objective QoS assessment is obtained from QoS monitoring and benchmark testing. Subjective assessments are based on user feedback and rating of the quality of the service after use and sometimes, service providers self-publish the QoS information of their services as contained in the service-level-agreement (SLA). When a user expresses their QoS requirements of a cloud service, they do so by specifying which of the QoS attributes are more important compared to the others and also set their desired values for each QoS attribute. Primarily QoS preferences are express by users specifying (1) The priority of each QoS attributes and (2) The desired values for each QoS attribute[23].

User's QoS priorities: Weights denoted QoS priorities of each QoS attributes are determined by computing the relative importance of each of the QoS attributes. Since cloud service cannot be evaluated based on one attribute alone, the degree of relevance of each attribute is not the same to the user. The user's order of priority for each of the attributes also contributes to the overall quality of the final option and determines the user's satisfaction about the option. For example, given the QoS attributes cost, security, availability and eco-friendliness, an order of importance for the QoS attributes for users A and B is shown in Fig. 1. The result of the evaluation of services available in the e-marketplace ought to have duly considered these inputs from the users[24].

User's QoS desired values: The QoS desired values define the users' desired ideal points for each of the QoS attributes. It comprises the aspiration and/or constraints for each QoS criteria. The QoS attributes possess specific values that define the actual non-functional performance of the cloud service. Users are able to define their own ideal values and/or constraints on those values, which serve as a benchmark to identifying suitable services that to satisfy the user's business objective (Fig. 1).

Table 1: Extrinsic and intrinsic factors affecting choice overload[6]

Factors	Description	Items
Extrinsic factors		
Decision task difficulty	This includes the structural properties of the decision problem such as	The number of alternatives available Number of attributes describing each alternative Time constraints Decision accountability Information presentation format
Choice set complexity	This involves the particular value of a choice alternatives or options	The similarity of among the alternatives The overall attractiveness of the alternatives
Intrinsic factors		
Preference uncertainty	This refers to the extent to which the decision maker has articulated preferences	Knowledge of product and product properties The availability of a well-defined ideal point
Decision goal	This refers to the consumer's goal involves choosing among the options in a given assortment	Decision intent (buying vs. browsing) Decision focus (choosing a set of alternative vs. choosing a particular one)

It is obvious that QoS priorities and desired values would differ from one user to the other, as shown in Fig. 1, thereby increasing the complexity of meeting user requirements[5]. User's QoS priorities and desired values define the utility functions which form the basis for the ranking of services and ultimately determines which alternative is selected by the user.

Service choice overload: The over-abundance of functionally equivalent services will leave users with the dilemma of which service to choose, a phenomenon that can be referred to as service choice overload[10,25,26]. The difficulties experienced when selecting from an assortment is referred to as choice overload (or overchoice). According to Toffler[26], who first introduced the term, "Over choice takes place when the advantages of diversity and individualization are cancelled by the complexity of buyer's decision-making process", in other words: The more the number of options, the lesser the motivation to choose or the lesser the satisfaction with the final choice[10,25]. In the context of this thesis, the term service choice overload was coined to describe this phenomenon, the consequence of which is that users may end up selecting a suboptimal option or not make any decision at all[25,26].

Four major factors (Table 1), classified into extrinsic and intrinsic factors, have been identified to impact choice overload in the literature[10].

Extrinsic factors refer to the decision aspect that borders on the structural characteristics of the problem, defined as decision task difficulty and choice set complexity, whereas, intrinsic factors pertain to the decision maker in particular and consist of preference uncertainty and decision goal[10]. Based on results from similar studies in the domain of consumer and assortment research deductions of how the aforementioned four factors affect service choice overload in cloud service e-marketplace is presented in Table 1[10].

Ideally, an e-marketplace contains a large number of cloud services with similar functionalities characterised by multiple attributes. Currently, most presentation formats of the search results to the users are unordered list of icons representing those alternatives that match user's keyword-based search criteria. For the users, employing a keyword-based search mechanism does not completely reflect well-defined ideal preferences for service attributes. In addition, user's preferences are also shrouded in vagueness and uncertainties[23]. Therefore, service choice overload can be minimized by using low cognitive demand decision support mechanisms for eliciting user's preferences, in a way that captures the vagueness and uncertainty that characterize human decision making; articulate those requirements into a query and apply some form of visualization heuristics to explore the result of the query, while allowing means for minor adjustments to initial query[5,11,27].

REVIEW OF CLOUD SERVICE SELECTION APPROACHES

Cloud service selection is concerned with the evaluation of the set of m services based on the user's preferences on the set of n QoS criteria. To simplify the selection process, a number of cloud service selection techniques have been proposed in the literature. These techniques can be broadly classified into three main approaches, namely-multi-criteria decision making (MCDM-based) techniques, optimization-based techniques and recommendation-based techniques[28,29]. The MCDA-based techniques have used multi-attribute utility theory (MAUT), ELECTRE, simple additive weighing (SAW), analytic hierarchical process (AHP) and TOPSIS. Optimization-based approaches model the cloud service section problem as follows-constraint satisfaction problem (CSP), multiple-choice knapsack problem and its variants and tree-search problem etc. the solution approaches in the optimization-based techniques are either optimal solutions or near-optimal solutions obtained by the use of heuristics, greedy algorithms, evolutionary algorithms etc. In recommendation-based techniques, the cloud service selection problem is formulated and solved as a recommendation problem. Asides the main three categories, some other cloud service selection techniques use semantic models or specific data model to represent cloud service QoS information while logic-based or similarity-based computations are employed to rank the cloud services. Furthermore, a number of techniques within each category have also applied uncertainty theories in the cloud service selection process. The uncertainty theories are employed to resolve user's subjective QoS requirements in evaluating each service option in other to determine the service that best approximates the user's QoS requirements. Next, a review of specific techniques in each category is presented in the next section.

MCDM-based techniques: Esposito *et al*.[30] proposed a technique to handle the uncertainty of users' QoS preferences in the face of untrustworthy indications concerning the QoS levels and prices of services posed by selfish providers. The technique uses fuzzy sets theory to handle uncertainty in users' subjective preferences to derive priority weights and employs a TOPSIS-based game theory-driven method to rank the alternatives. Qu and Buyya[23] presented a personalised trust evaluation system to support IaaS selection. The technique employed membership functions and fuzzy hedges to elicit users' subjective QoS requirements and generated trust levels for each cloud service through a hierarchical fuzzy inference system. Garg *et al*.[20] proposed SMICloud, an approach based on SMI QoS model and uses historical QoS measurements, combined with self-published QoS information by service providers to derive the actual QoS values. The SMICloud is an AHP-based implementation that assigns weights to QoS attributes by considering the interdependence between them, thereby providing a quantitative basis to rank cloud services. The technique by Rehman *et al*.[31] utilised the QoS history of cloud services from different time periods and employs a parallelized MCDM-based method, which combines TOPSIS and ELECTRE, to rank all cloud services in each time period in with respect to users' preferences before combining the results used in ranking the alternatives.

Optimization-based techniques: CloudAdvisor[32] enables interactive exploration of various cloud configurations and recommends optimal configurations in line with users' workload and preferences which cover user's budget, performance expectation and energy saving desire for a given workload. The estimated near optimal configuration is determined using a constraint optimisation method that considers user's preferences, availability of resources and dependency of proper hardware and software. The constraint optimisation problem is solved using A* search algorithm and near-optimal configurations offered by other providers is formulated as a knapsack problem, solved by a benchmarking based approximation technique based on a greedy algorithm. CloudPick[33] simplifies cross-cloud deployment via QoS modelling and deployment optimisation. CloudPick uses two deployment optimisation algorithms based on genetic and forward-checking-based backtracking (FCBB) algorithms to deploy networks of virtual appliances based on minimum cost, high reliability and low latency. Qian *et al*.[34] introduced cloud service selection (CSS) as an IaaS selection technique. The technique manages the scalability issue that arises from a large number of data centres and applications by introducing a heuristics-based stepwise application placement optimisation algorithm that is able to discover near optimal solution in a short time, with the objective of minimising cost and maximising high QoS performance of the applications.

Recommendation-based techniques: The CSTrust[35] determined the trustworthiness of cloud services by combining QoS-predictions obtained from objective assessment and subjective user satisfaction estimation. CSTrust uses collaborative filtering and a utility function to improve the accuracy of QoS value prediction, by predicting the missing QoS value of quantitative attributes from previous usage scenario of other similar services. In the same line of study, Yu[36] proposed CloudRec as a cloud selection framework that utilises a user-focused strategy for personalised QoS evaluation of cloud services. The CloudRec is able to use an iterative algorithm on community-based QoS assessment model to discover a set of similar user and service communities from scarce and large-scale QoS data, as users connect to approximate the QoS values of unknown cloud services. The CloudRec employs the regularised posterior probabilistic non-negative matrix factorization (RPPNMF), a technique that efficiently handles data scarcity that often characterises the cloud environment. Ma and Hu[37] proposed, RecTIN, a cloud service recommendation technique that utilises ternary interval numbers (TIN). The TIN enabled the description of QoS evaluations from existing users in other to determine the QoS trustworthiness of a cloud service for potential cloud service users. The K-means clustering algorithm was employed on the basis of multi-attributes trust aggregation which uses fuzzy-AHP to rank TIN while selecting trustworthy services.

Other cloud service selection techniques: Cloud Recommender[38] is a declarative technique for the selection of cloud-based infrastructure services. In Cloud Recommender, cloud service configurations are captured in an ontology-based data model and manipulated using regular expressions and SQL. The domain knowledge representing a variety of infrastructure service configurations are identified and formalised by a declarative logic-centred language and implemented as a recommender module atop a relational data model. An extensible approach for cloud storage service selection was proposed by Ruiz-Alvarez and Humphrey[39]. The approach is used to select the service that best matches each dataset of a given target user application by relying on XML schema containing service capabilities and attributes of each cloud storage system. To rank and select suitable cloud services, Baranwal and Vidyarthi[40] applied ranked voting method combined with data envelopment analysis (DEA) technique. The technique considers each QoS criteria as voters and the cloud providers are alternatives to be voted for. Since DEA suggests more than one optimal alternative, additional rank voting techniques are required to discriminate optimal alternatives.

Comparative analyses of existing techniques: In other to situate the requirements for a QoS-based service selection technique that will suffice in a cloud e-marketplace context, a comparative analysis of existing techniques was performed based on the following analysis criteria: (a) Elicitation of subjective QoS preferences in terms of both user's priority and ideal values on QoS attributes, (b) Employs a graphical user interface (GUI) in the elicitation of user's preferences, (c) Efficiently rank a large number of services with respect to user's preferences and (d) Incorporates a QoS-driven visualization mechanism to explore the top ranking services that match user's QoS preferences.

From Table 2, it is obvious that only 3 out of 13 techniques reviewed elicit subjective QoS preferences and only 2 elicits QoS values, meanwhile, RecTIN and Qu and Buyya[23] are the only techniques that elicit both the QoS priority and values from users. Nine techniques can rank a large number of services with respect to users QoS preferences to identify top-ranking services. Just 5 techniques employed the use of a GUI through which users can express their QoS preferences, while only 3 of 13 techniques reviewed use a form of visualisation to present ranking results.

Table 2: Comparative analysis of existing cloud service selection techniques

Technique category	Sources	Summary of techniques	Elicit subjective QoS priority	Elicit subjective QoS values	Rank large services number	Employ GUI	Incorporate visualization
MCDM-based	Qu and Buyya[23]	Hierarchical fuzzy inference	■	■	■	■	-
	Esposito *et al.*[30]	Fuzzy inference, TOPSIS, game theory	■	-	■	-	-
	SMICloud[20]	AHP	-	-	-	-	■
	Rehman *et al.*[31]	TOPSIS, ELECTRE	-	-	■	-	-
Optimization-based	CloudAdvisor[32]	Constraint optimisation satisfaction with greedy algorithm	-	-	■	■	■
	CloudPick[33]	Genetic algorithm-based description logic matching	-	-	-	■	-
	CSS[34]	Heuristics algorithm	-	-	■	-	-
Recommendation-based	CSTrust[35]	Collaborative filtering and utility computation	-	-	■	-	-
	CloudRec[36]	Regularised posterior probabilistic nonnegative matrix factorization	-	-	■	-	-
	RecTIn[37]	Ternary Interval number, fuzzy-AHP	■	■	-	-	-
Others	Cloud Recommender[38]	Declarative SQL, ontology mapping	-	-	■	■	■
	Ruiz-Alvarez and Humphrey[39]	Matching algorithm	-	-	-	■	-
	Baranwal *et al.*[40]	Rank voting method, data envelope analysis	-	-	■	-	-

■: Supported, -: Not Supported

DESIGN CONSIDERATIONS FOR CLOUD SERVICE SELECTION FRAMEWORK

The aforementioned analyses revealed the deficiencies of existing service selection techniques in reducing service choice overload in an e-marketplace context. Therefore, a set of requirements for the design of techniques that will suffice for service selection in cloud e-marketplaces is proposed. The requirements are as follows:

Requirement 1

Ability to elicit both subjective QoS priorities and QoS desired values: Although requirements are usually vaguely expressed by users[12], a number of existing techniques require that user's QoS preferences are specified in exact or precise terms. Users conveniently rely on the use of subjective descriptions that approximates their preferences. Noting that the ranking of services in e-marketplace depends on the user's QoS preferences, the accuracy of the ranking should not be compromised by the use of subjective approximate descriptions. Nonetheless, giving users the flexibility of expressing QoS requirements by allowing for subjective descriptions is a plus to the user experience, as the cognitive load of having to craft crisp values is reduced[8]. In addition, Qu and Buyya[23] observed that user's QoS requirements can indeed be specified in terms of priorities (i.e., the user's relative importance attached the QoS attribute) and desired values. Both preference dimensions are two important considerations for determining which cloud services to select. To satisfy requirement 1, cloud service selection techniques for cloud e-marketplaces should be able to capture the vagueness that accompanies users' expression of both the QoS priorities and desired values for each QoS attribute and use these preference information to rank cloud services.

Requirement 2

Ability to rank a large number of services: Cloud e-marketplaces are characterised by a large portfolio of cloud services numbering to several hundreds of services that possess similar functionalities. Some of the techniques proposed in the literature are best suited when there are a few service alternatives to select from. Ideally, it should be possible to evaluate each service alternative in other to identify those services that best match user's preferences irrespective of the number of services available. Cloud service selection techniques for cloud e-marketplaces should be able to efficiently and accurately perform such evaluation with minimal computational overhead.

Requirement 3

Ability to capture subjective QoS preferences with interactive GUI: The user interface underscores input and output features of the cloud e-marketplace. The input dimension refers to how a user expresses the QoS preferences that reflect their business objectives, whereas the output dimension how the manner the result of those requests to the user[41]. The graphical user interface should intuitively support the capturing of subjective QoS preferences in a manner that is convenient to the user. Besides, the user interface design should appeal to the user's perception as this affects user's attitude to what comes out through and from it the interface, while ultimately impacting on the user satisfaction[42].

Requirement 4

Incorporate visualisation mechanism for service exploration: Service choice overload is influenced by the manner in which the alternatives are presented. The alternatives in commercial e-marketplaces are usually presented as a listing of service icons or logos, without any basis for the ordering. In situations where the users have insufficient knowledge about the service they prefer, users are required to analyse each service one after the other to identify a desirable cloud service. But results showing the ranking of cloud services can be presented in form of textual list (as is in many existing techniques), in a table or the use of more sophisticated information visualisation techniques. The later, compared to the others, employ techniques that leverage on human's visual processing ability to process elements in a pictorial form faster and derive greater insight and comprehension than from mere text[43,44]. Search or rankings result should be innovatively presented in a way that eases understanding, encourages the comparison of alternatives and reduces cognitive load and reduce service choice overload[38].

A QOS-DRIVEN CLOUD SERVICE SELECTION FRAMEWORK

Based on the set of requirements identified, a QoS-driven framework for cloud service selection in e-marketplaces is presented (Fig. 2). The framework is proposed to reduce service choice overload and improve the user experience of cloud service e-marketplaces and comprise of three main modules namely, Graphical user interface and visualisation module, preference processing module and the QoS-based ranking module. Users are expected to interact with the e-marketplace via the GUI and visualisation module, while the preferences elicited via the GUI component is processed in the

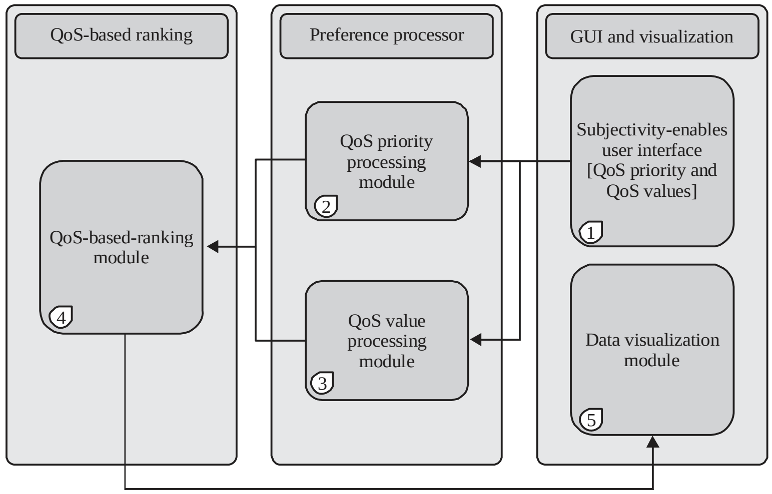

Fig. 2: Proposed QoS-based cloud service selection framework. GUI: Graphical user interface

preference processing module and used to rank the available services in the service catalogue. The rank results are presented to the user via the visualisation component.

GUI and visualization module: The user interface (UI) is the visual medium through which the user interacts and engages the e-marketplace and it plays a very prominent role in determining the usability and user experience in the marketplace environment[45]. Since it is more convenient to express user preferences in a way that is more akin to human expressions, the subjectivity-enabled user interface elements of the proposed framework support the elicitation of subjective preferences. Users can use visual elements (e.g. sliders, drop-down menu, textboxes, checkboxes etc.) underlined by subjectivity theories (e.g., fuzzy set, rough set, etc.) to conveniently express their QoS preferences using linguistic terminologies[23,30]. In addition, the framework advances the inclusion of intuitive data visualisation formats, such as parallel coordinate charts, radial charts, bubble graph, line graphs etc. to enable the exploration of services, while simplifying service selection in e-marketplaces[46].

Preference processing module: In this module, the preferences captured via the subjectivity-enable GUI module are analysed to interpret the user's preferences. The user's QoS priorities are determined by employing plausible techniques for deriving attribute weights from subjectivity user inputs, e.g. fuzzy pairwise comparisons. Also, based on uncertainty theories like fuzzy set or fuzzy decision-making techniques, the user's QoS values captured are processed to obtain the actual ideal QoS values that reflect the user's aspiration concerning the QoS attributes. The processed preferences become the input into the QoS-based ranking module.

QoS-based ranking module: This module uses the processed QoS preferences to evaluate and rank each service in the e-marketplace service catalogue. The QoS preferences are used in some utility functions that are used to evaluate the overall performance of all the services. Based on the evaluation of the utility functions the services in the catalogue are ranked in accordance to the nearness of the aggregated QoS attributes of the services to the user's QoS preferences. The top-ranked services become the data inputted into the visualisation component of the GUI for service exploration and eventual selection.

DISCUSSION

The implications of the proposed framework were discussed to reduce service choice overload in the light of the set of requirements identified. The proposed framework fulfils requirement 1 by eliciting both the QoS priorities and QoS values and combining both QoS information in determining the rank of all the services that are capable of meeting user's functional requirements. In other to ensure that user's preferences are well captured, the proposed framework satisfies requirement 3 by proposing the integration of subjectivity based user interface widgets to both elicit vague user priorities and values for each QoS attributes. Since the user's perception of the interface affects their attitude to what comes out of it and ultimately affects user satisfaction, the proposed GUI design can intuitively capture the user's requests more naturally[40]. The interface widgets enable subjective pairwise comparisons of QoS attributes to determine user's priority on QoS attributes. The advantage of pairwise comparisons to derive priority weights of each QoS attribute from comparison matrices far outweighs direct and arbitrary assignment of weights[47]. Fuzzy-AHP is a method that provides a measure of flexibility in comparison judgment by ensuring subjectivity values in the Saaty's discreet scale[48].

Although estimating relative pairwise comparison can be made numerically, graphically, or linguistically[49], a graphical and linguistic approach further reduces cognitive load on the user and is easier than expecting the user to enter crisp numeric ratios. Similarly, expressing QoS values also benefits from the flexibility provided by employing fuzzy set theory, linguistic variables defined by membership functions can be used together with hedges as the underlay of interface widgets such as text boxes, checkboxes, drop-down menus etc.

The cloud e-marketplaces are characterised by a large set of services, which are most times functionally equivalent. The proposed framework fulfils requirements 2, by employing utility functions capable of accurately evaluating and ranking a large set of services in accordance with user's QoS preferences. The proposed framework fulfils requirement 4 by incorporating a visualisation mechanism for improving the understanding of the rationale for the rankings of cloud services based on the user's preferences. Most result pages of commercial e-marketplaces do not provide transparency into the rationale behind the ranking results[21]. Arguably, confidence in the ranking results would be enhanced if users are privy to the knowledge of the underlying rationale. The use of visualisation mechanism explicitly would show the relationships of the top ranked cloud services as well as the underlying structure of the QoS space[21]. The visualisation mechanism employed would enable easier comparison of search results and simplify decision making.

The growing trend for personalised products and services in online shopping context requires that usability and user experience be given top priority if the vision of cloud service e-marketplace is to be re alised[50]. Usability is a measure of how easy to use, effective a system is (i.e., did the user achieve the goal?) and efficient a system is (i.e., how long it took the user to achieve the goal?), while user experience defines the feelings of the user in utilizing the system (e.g., is the interaction satisfying, enjoyable, engaging)[51]. However, the evaluations of cloud service selection techniques reported in literature focused more on performance and accuracy in ranking services. Therefore, similar to the evaluation of recommender systems, a more holistic evaluation of cloud service selection techniques should include usability and user experience dimensions.

CONCLUSION

A small business's resolution to adopt a new cloud-based service would require decision support in navigating the plethora of services. Decision support becomes essential, noting that such decision involves the consideration of multiple criteria with heterogeneous units of measurements, which must be compared to a variety of services, often using vague or subjective information. As a consequence of a comparative review of existing techniques, this paper identified a set of requirements for the design of service selection techniques to reduce choice service overload in cloud e-marketplace. Thereafter, a framework for service selection in cloud e-marketplace is proposed based on the requirements identified. As a way of evaluation, the researcher intends to measure the effectiveness and suitability of the framework regarding its user experience dimensions in both experimental and real-life scenarios.

SIGNIFICANCE STATEMENT

This study proposes a framework to guide the design of cloud service selection technique to reduce service choice overload often experienced by users. This study will help researchers to uncover the vital dimensions of cloud service ranking and selection as it relates to improved user experience in cloud e-marketplace context that is yet to be fully explored in the techniques proposed by other researchers. Thus a new framework on cloud service selection may be arrived at.

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