Towards a Fuzzy-oriented Framework for Service Selection in Cloud e-Marketplaces

Azubuike Ezenwoke[1], Olawande Daramola[1] and Matthew Adigun[2]
[1]*Covenant University, Ota, Nigeria*
[2]*Center for Excellence for mobile e-services, University of Zululand, South Africa*

Keywords: Cloud Service Selection, e-Marketplace, Constraint Satisfaction, Fuzzy Decision Making, Fuzzy AHP, Visualization.

Abstract: The growing popularity of cloud services requires service selection platforms that offer enhanced user experience in terms of handling complex user requirements, elicitation of quality of service (QoS) requirements, and presentation of search results to aid decision making. So far, none of the existing cloud service selection approaches has provided a framework that wholly possesses these attributes. In this paper, we proposed a fuzzy-oriented framework that could facilitate enhanced user experience in cloud e-marketplaces through formal composition of atomic services to satisfy complex user requirements, elicitation and processing of subjective user QoS requirements, and presentation of search results in a visually intuitive way that aids users' decision making. To do this, an integration of key concepts such as constrained-based reasoning on feature models, fuzzy pairwise comparison of QoS attributes, fuzzy decision making, and information visualization have been used. The applicability of the framework is illustrated with an example of Customer Relationship Management as a Service.

1 INTRODUCTION

The growing popularity of cloud services requires service selection platforms that enable the composition of atomic services to satisfy complex user requirements, and highlight the quality of services (QoS) attributes of these value-added services under one e-marketplace structure (Akolkar et al., 2012; Gatzioura et al., 2012). Despite their successes, commercial cloud e-marketplaces (e.g. AppExchange and SaaSMax) do not yet enable dynamic composition, and employ keyword-based search mechanisms that do not consider user's QoS requirements, nor support the elicitation of these requirements in ways akin to subjective human expressions. In addition, search results on these platforms are presented as unordered lists of icons, with little or no comparison apparatus that simplifies decision making. Existing cloud selection approaches (see Figure 1) do not currently provide the sophistication to optimize user experience in the e-marketplace (Akolkar et al., 2012).

For example, some approaches only allow users to make selection from a predefined list of atomic services, which does not address complex situations where a user's requirements extend beyond what atomic services can provide (e.g. Esposito et al., 2015). Additionally, some other methods lack the flexibility to accommodate subjective QoS inputs, and demand that a user specifies requirements in exact terms, e.g. (Wittern et al., 2012; Rehman et al., 2011).

Qu and Buyya (2014) observed that user's QoS requirements can indeed be specified in terms of preferences (user's priority for each QoS dimension) and aspiration (user's values for QoS dimension) as two important considerations for determining which cloud services to select. However, some existing approaches that have considered subjectivity in user requirements elicit either QoS preferences or QoS aspirations alone from the user but rarely both (e.g. Esposito et al., 2015; Yu and Zhang, 2014). Still, some others (e.g. Esposito et al., 2015; Mirmotalebi et al., 2012; Qu and Buyya, 2014; Rehman et al., 2011) require users to assign priority weights to QoS attributes, with the downside of being less accurate compared to pairwise comparison of the relative importance of QoS attributes (Millet, 1997).

Again, many approaches (e.g. Esposito et al., 2015; Yu and Zhang, 2014; Qu and Buyya, 2014;

Ezenwoke, A., Daramola, O. and Adigun, M.
Towards a Fuzzy-oriented Framework for Service Selection in Cloud e-Marketplaces.
DOI: 10.5220/0006365306320637
In *Proceedings of the 7th International Conference on Cloud Computing and Services Science (CLOSER 2017)*, pages 604-609
ISBN: 978-989-758-243-1

Wittern et al., 2012) present search results in a textual list or table format, that do not make obvious the trade-off among search results, which makes it more cognitively demanding for users to make decisions based on search results (Beets and Wesson, 2011). Ultimately, these identified limitations will hamper user experience in the cloud service e-marketplace.

Source	Approach Summary	Compose Atomic Services	Elicit QoS Preference	Elicit QoS Aspiration	Subjective QoS Preference	Subjective QoS Aspiration	Visualization
Esposito et al. (2015)	Fuzzy Inference, TOPSIS, Dempster-Shafer theory	○	●	●	●	○	○
Yu and Zhang (2014)	Interval Numbers & TOPSIS	○	○	●	○	●	○
Qu and Buyya (2014)	Hierarchical Fuzzy Inference	○	●	●	●	●	○
Kwon and Seo (2013)	Fuzzy-AHP	○	●	○	●	○	●
Wittern et al. (2012)	Matching Algorithm &Constraint Satisfaction	●	○	●	○	○	○
Mirmotalebi et al. (2012)	Similarity Computation	○	●	●	○	●	○
Rehman et al. (2011)	Similarity Computation	○	●	●	○	○	○
●=Satisfied ○=Not Satisfied							

Figure 1: Summary of Related works.

Hence, in this paper, we present an integrated framework for cloud service selection that supports fuzzy-oriented decision making, and formal composition of atomic services in response to complex user requirements. This is proposed as an approach to cloud service selection that caters for observed limitations in existing cloud service selection approaches. To do this, we employed an integration of relevant concepts such as: 1) feature modelling - to organize atomic services within the cloud ecosystem; 2) constraint-based reasoning - to guide formal service composition on the fly; 3) Fuzzy-based prioritization and analysis methods – to handle subjective user QoS preferences and aspiration; and 4) information visualization – to enable easy comparison of query results along multiple QoS dimensions. Our framework is proposed as an improvement to existing cloud service selection approaches.

The rest of this paper is structured as follows: Section 2 provides some background and Section 3 contains related works. Our framework is presented in Section 4, while its applicability is presented in Section 5. Section 6 discusses the implication of our framework and Section 7 contains conclusion and future work.

2 BACKGROUND

Cloud Services Ecosystem: A cloud services ecosystem is an environment that host heterogeneous cloud service offerings from different providers, and affords the opportunity of collaborations. A cloud service ecosystem is analogous to a software product line (SPL).

Automated Reasoning on Feature Models: The cornerstones of SPL endeavours are: a knowledge model (e.g. feature model) that captures the relationships among the components based on variabilities, and computer-aided reasoning to derive useful information from the model.

A feature model (FM) is a hierarchically arranged collection of features and consists of the inter-relationships between a parent feature and its child features, and a set of cross–tree constraints that define the criteria for feature inclusion or exclusion (Berger et al., 2014). There are 3 types of FM: basic, cardinality-based and extended feature models (EFM) (Benavides et al., 2010). We adopted EFM because it allows the modelling of cloud services, their QoS attributes and relationship constraints more naturally.

Automated reasoning is performed by mapping the FM into logic-based encodings (e.g. description logic, propositional logic, and constraint programming), and encodings are inputted into solvers to find valid compositions of atomic services (Benavides et al., 2010). The overall QoS attributes of the valid combinations is determined by the QoS factors of constituent services, and are computed using QoS aggregation functions. Types and application of QoS aggregation functions can be found in (Mohabbati et al., 2011).

Fuzzy Set Theory: Fuzzy set theory is effective to capture vagueness that characterizes user QoS requirements (Qu and Buyya, 2014; Zadeh, 1974). Each QoS attribute can be represented as a linguistic variable and users can express QoS preferences and aspiration using linguistic terms. In this paper, preference weights were derived using fuzzy pairwise comparison in Fuzzy-AHP; while QoS aspirations were elicited and analysed as a system of fuzzy goals and constraints (Bellman and Zadeh, 1970).

3 RELATED WORKS

A number of approaches for selecting cloud services exist in the literature (see Figure 1). The approach in

(Esposito et al., 2015) uses fuzzy sets theory to handle uncertainty in users' preferences and a TOPSIS-based method to rank services. Yu and Zhang (2014) proposed a SaaS selection model for group users, by eliciting vague QoS preferences using interval numbers. The approach of Qu and Buyya (2014) employs a hierarchical fuzzy inference system for cloud service selection, while Kwon and Seo (2013) described an IaaS selection model based on Fuzzy-AHP. Wittern et al. (2012) presented an approach to harness cloud service capabilities using variability model and likely alternatives are subjected to a preference-based ranking process. Mirmotalebi et al. (2012) proposed an approach for ranking cloud services based on both explicit and implicit user preferences. Rehman et al. (2011) proposed two methods for service selection based on similarity of users' requirements and service's properties.

From the summary of relevant previous efforts shown in Figure 1, all approaches, except Wittern et al. (2012), cannot compose atomic services to meet complex user requirements. Furthermore, only Qu and Buyya (2014) elicits both subjective QoS preferences and aspirations, while only Kwon and Seo (2012) incorporates some type of visualization to aid service selection. In contrast, our proposed framework will enable composition of atomic services, elicitation of subjective QoS requirements and result visualization to aid selection in order to foster improved user experience during service selection in cloud e-marketplaces.

4 PROPOSED FRAMEWORK

This paper proposes a fuzzy-oriented framework (see Figure 2) for selecting cloud services in cloud e-marketplace.

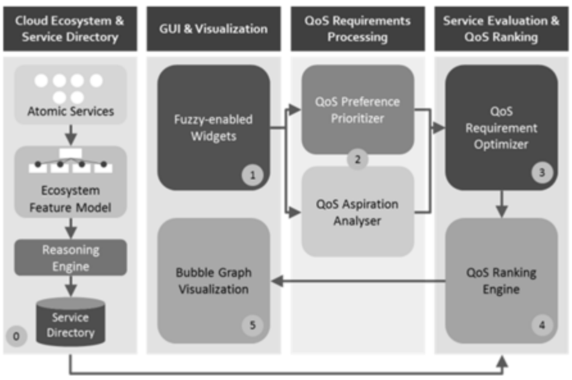

Figure 2: Proposed framework.

The framework comprises four modules namely: Cloud ecosystem and service directory, GUI & visualization, QoS requirement processing, and Service evaluation & QoS ranking.

In step 0, the atomic services are combined to realize the set of composite services offered in the e-marketplace. Subjective QoS requirements are then provided (step1), processed (step 2), optimized (step 3), and used to rank services in the directory (step 4). The ranked results are shown to the users via bubble graph visualization (step 5). We shall discuss each module in details subsequently.

4.1 Cloud Ecosystem and Service Directory

The framework uses the extended feature model notations (Benavides et al., 2010), to model the cloud ecosystem feature model (CEFM). The CEFM is mapped as a constraint satisfaction problem, and the Choco-based reasoning engine (*www.choco-solver.org*) reasons with a Depth-First search algorithm to derive all valid mappings. Possible combinations of atomic services that can be generated from the pool of atomic services are made available in the e-marketplace based on former composition approaches (Akolkar et al., 2012).

4.2 GUI and Visualization

The framework integrates fuzzy-enabled web-based widgets comprising sliders, drop-down menus and textboxes for eliciting vague preferences and aspirations, while bubble graph visualization is employed to improve understanding of the relationship among the ranked services.

Users can indicate preferences by pairwise comparison for each QoS attribute by adjusting the slider handle (see figure 3). The slider bar has two colour codes that corresponds to the QoS attributes, and indicates the level of preference for a QoS attribute; the lengthier colour means user prefers a QoS attributes more than the other. The positions of the slider handle are underlined by fuzzy numbers, from the fuzzified Saaty scale.

Since humans derive better insight from a picture faster than mere text, the use of information visualization to aid service selection improves user experience (Spence, 2014). The use of bubble graph visualization improves the understanding of how each service in the ranking relates with others (see Figure 4). Each service is represented as a bubble (shape), using colours, sizes and x-y coordinates to show services in the QoS information space. These dimensions (colours, size and x- and y coordinates) represents four QoS attributes (e.g. availability, cost, response time, security reliability etc.) simultaneously and shows the relationship among the top ranked cloud services; thereby, enabling effective comparison.

4.3 QoS Requirements Processing

QoS Preference Prioritizer (QPP): The QPP module ensures consistency in the pairwise judgment and uses the geometric mean method to derive priority weights. Defining comparison ratios as fuzzy numbers are a better way to capture user's claim about the relative importance of criteria. To prioritize user's QoS preferences, the QPP employs Fuzzy AHP-based approach. In FAHP, exact comparison ratio a_{ij} is represented as a fuzzy number, $\tilde{a}_{ij}$, based on 9 fuzzy linguistic terms described in the fuzzified Saaty's scale (Buckley, 1985). The user performs pairwise comparison for all QoS criteria, which fills the fuzzy comparison matrix. For example, a user's degree of importance of security criterion over availability can be expressed by the fuzzy number "about strongly important" $\tilde{a}_{sec,avail} = (6,7,8)$. The corresponding reciprocal from on the fuzzy comparison matrix becomes $\tilde{a}_{avail,sec} = (\frac{1}{8},\frac{1}{7},\frac{1}{6})$. The fuzzy priority vector, $\tilde{w}^T$, is obtained by applying the geometric mean prioritization method (Buckley, 1985).

QoS Aspiration Analyser (QAA): The QAA module synthetizes user's QoS values based on fuzzy decision making, comprising membership functions framed as fuzzy goal and constraints (Bellman and Zadeh, 1970). Since the linguistic terminologies describing the QoS aspiration reflect the semantic approximations of user's intent, resolving the fuzzy decision results in optimal set of QoS values that approximate user's QoS intent. Table 1 shows sample linguistic goals and constraints for *availability* QoS attribute.

Table 1: QoS goals and constraints for Availability QoS.

QoS	Linguistic QoS Goals	Linguistic QoS Constraints
Availability	High Medium Low	Substantial greater than x In the vicinity of x About x Very Close to

Examples of a fuzzy goal and constraints are "*The Availability of the service should be High*", and "*Availability should be About* x"; where x is a specific value as indicated by the user.

4.4 Service Evaluation and QoS Ranking

QoS Requirements Optimizer (QRP): The QRP component computes the optimal QoS values that describe user's requirements based on the QoS information of all the services in the service directory. The inputs into this component are the priority weights and the value for QoS attributes. The framework defines two utility functions: a Simple Addictive Weighting (SAW) function (1) and exponential Euclidean distance metric (eEUD) (2), to evaluate the performance of each service alternative w.r.t user requirements. SAW is used to determine the QoS properties of the alternative with the highest utility, while eEUD computes the QoS properties closest to users' requirements.

$$A_i = \sum w_j x_{ij} \tag{1}$$

x_{ij} = j^{th} QoS value of i^{th} service; w_j = j^{th} QoS weight.

$$eEUD_i(x,y) = \sqrt{\sum_{j=1}^{m} e^{w_j(x_j^2 - y_j^2)}} \tag{2}$$

x_j and y_j are the values of the j^{th} QoS properties of i^{th} cloud service and user requirements respectively. The results from the two functions are used to construct the optimal QoS requirements.

QoS Ranking Engine: The output from the QRP forms the basis for ranking the services in the directory. The main technique used in this module is a nearest neighbour algorithm, based on (2). The output is the top-k services fed into the bubble graph visualization.

5 ILLUSTRATION

A scenario of a customer relationship management as a service (CRMaaS) ecosystem and e-marketplace was reported in (Ezenwoke, 2016). The CRMaaS is made up of 5 modules (contact manager, database, marketing, social media analytics and cloud platform) and 14 atomic services to fulfil the modules. The modules and atomic services were modelled using extended feature modelling notations and a constraint-based reasoning engine is used to derive a set of 38 valid compositions based on the constraints guiding the relationship of the modules and atomic services.

Based on the 38 valid composite services reported in (Ezenwoke, 2017), Table 2 shows four QoS attributes whose ranges are represented by linguistic variable and underlying membership functions. Table 3 and Table 4 show a sample user's preferences and aspiration over the 4 QoS attributes. Figure 3 depicts how the user's available QoS requirements are captured using the GUI module. Table 5 contains the sample optimal values representing user's QoS requirements. Table 6 shows the ranking of service with respect to user's requirements and the bubble graph visualization of the ranking is shown in Figure 4.

Table 2: QoS Attributes and linguistic variables.

QoS	Fuzzy sets	Membership Function
Availability	Very High, High, Medium, Low	Trapezoidal Membership Function
Response Time	Low, Acceptable, Below Average	
Reliability	Very High, high, Average, Low	
Cost	Premium, Standard, Moderate, Cheap	

Table 3: User's QoS Preferences.

QoS	Fuzzy Judgement	QoS
Availability	Extremely more important than	Resp.Time
Availability	Extremely less important than	Reliability
Availability	Somewhat Less important than	Cost

Table 4: User's QoS Aspiration.

QoS	Goal	Constraints
Availability	Very High	In the Vicinity of 98%
Resp. Time	Low	Very close to 400ms
Reliability	Very High	In the Vicinity of 75%
Cost	Premium	In the Vicinity of 400$

Table 5: Sample of complete user QoS requirements.

QoS	Preference	Aspiration
Availability	0.1242	98.49
Resp. Time	0.1237	489.46
Reliability	0.5798	75.43
Cost	0.1724	390.64

Table 6: Top ten services that match user requirements.

Rank	ID	Avail. (%)	R. Time (ms)	Reliab. (%)	Cost ($/Mon)
1	S3	98.67	546.24	75.43	390.64
2	S17	99.03	546.24	75.43	386.15
3	S10	98.49	546.24	74.72	385.64
4	S35	98.62	489.46	75.72	360.98
5	S19	99.51	559.35	76	390.48
6	S4	97.16	546.24	72.48	381.15
7	S18	97.53	546.24	72.48	376.66
8	S20	98.01	559.35	73.04	380.99
9	S7	98.29	526.12	74.19	354.14
10	S32	98.02	551.35	75.62	360.46

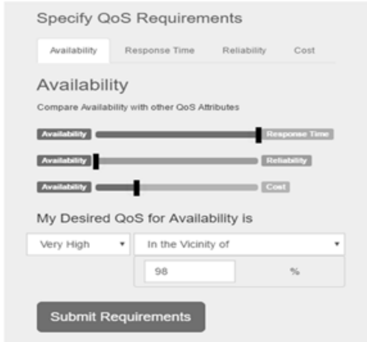

Figure 3: Availability QoS Requirements for User's Requirements.

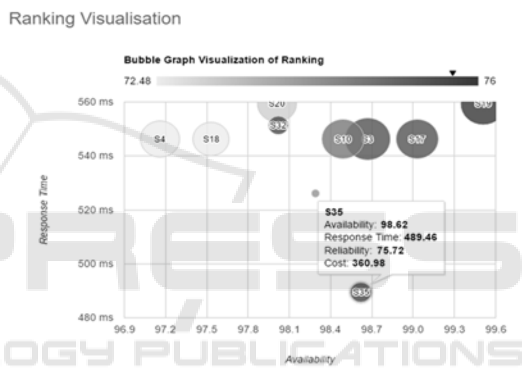

Figure 4: Bubble Graph for Ranked Services for User Requirements: showing details for Service_ID 35 on mouse over.

6 DISCUSSION

The proposed framework has the potential to address some of the limitations that have been observed in existing cloud selection techniques. These are elaborated as follows:

Handling of Complex user Requirements that are Beyond Capability of Individual Atomic Services: The framework automates the composition of atomic services to satisfy complex user requirements, and updates the service directory by capturing scenarios of new entrants and exists of atomic services. With our framework, the number of potential composite offerings can be planned a priori by e-marketplace provider; similarly, atomic service providers can drive the competitiveness of their offerings from knowing the number of composite offerings features their services.

Enabling Flexibility to Accommodate Subjective QoS Inputs: In addition, the framework promotes the interface design of the e-marketplace with user experience intended. This way, users can easily express QoS requirements and find optimal service(s) within the shortest time. The fuzzy-enabled widgets integrated in our framework allow users the flexibility of expressing subjective QoS requirements.

Improved Presentation Format for Search Results to Aid Decision Making: Having obtained a ranking of cloud services with respect to user QoS requirements, the bubble graph used in the framework enables comparison of the top ranked services in one single view, thus simplifying the selection decision compared to tabular listing.

7 CONCLUSIONS

In cloud service e-marketplace, service providers should be able to join the ecosystem easily, and user should conveniently express subjective requirements (Akolkar et al., 2012), and to particularly explore services without being overwhelmed by so many choices. The main contribution of this paper is a cloud service selection framework that incorporates mechanisms to: 1) compose atomic services on the fly to satisfy complex users' requirements; 2) allow users the flexibility of expressing QoS requirements; both preferences and aspirations, and do so using subjective descriptors that is more akin to human judgment; 3) reduce choice overload by showing only the top best services in a manner that facilitates easy comparison for effective decision making. In the nearest future, we plan to fully operationalize the framework and evaluate its effectiveness in the context of a real cloud service e-marketplace.

REFERENCES

Akolkar, R., Chefalas, T., Laredo, J., Peng, C.-S., Sailer, A., Schaffa, F., Silva-Lepe, I.a. and Tao, T., 2012. The Future of Service Marketplaces in the Cloud. *In IEEE 8th World Congress on Services*, pages 262-269.

Beets, S. and Wesson, J. (2011). Using information visualization to support web service discovery. In SAICSIT, pages 11-20.

Bellman, R. and Zadeh, L. (1970). Decision making in fuzzy environment. *MonogemenlScience*. 141-164.

Benavides, D., Segura, S. and Ruiz-Cortes, A. (2010). Automated analysis of feature models 20 years later: A literature review. *Information Systems*. 615-636.

Berger, T., Pfeiffer, R.-H., Tartler, R., Dienst, S., Czarnecki, K., Wasowski, A. and She, S. (2014) Variability Mechanisms in Software Ecosystems. *Information and Software Technology*, 56(11):1520-1535.

Buckley, J. (1985) Fuzzy hierarchical analysis. *Fuzzy Sets and Systems*, 233-247.

Esposito, C., Ficco, M., Palmieri, F. and Castiglione, A. (2015). Smart Cloud Storage Service Selection Based on Fuzzy Logic, Theory of Evidence and Game Theory. In *IEEE Transactions on Computers*, Available: 0018-9340.

Ezenwoke, A., (2017). Using constraint reasoning on feature models to populate ecosystem-driven cloud services e-marketplace. Covenant University Technical Report.[Online]. Available at: eprints.covenantuniversity.edu.ng/7624/

Gatzioura, A., Menychtas, A., Moulos, V. and Varvarigou, T. (2012). Incorporating Business Intelligence in Cloud Marketplaces. In IEEE 10th International Symposium on Parallel and Distributed Processing with Applications, pages 466-472.

Millet, I. (1997). The effectiveness of alternative preference elicitation methods in the analytic hierarchy process, *Journal of Multi-Criteria Decision Analysis*, 41-51.

Mirmotalebi, R., Ding, C. and Chi, C. (2012). Modeling User's Non-functional Preferences for Personalized Service Ranking. *Service-Oriented Computing*.

Mohabbati, B., Gašević, D., Hatala, M., Asadi, M., Bagheri, E. and Bošković, M. (2011). A Quality Aggregation Model for Service-Oriented Software Product Lines Based on Variability and Composition Patterns. *Service-Oriented Computing*, 436-451.

Qu, C. and Buyya, R. (2014). A Cloud Trust Evaluation System using Hierarchical Fuzzy Inference System for Service Selection. In *28th International Conference on Advanced Information Networking and Applications*, pages 850-857.

Rehman, Z, Hussain, F. and Hussainz, O. (2011). Towards Multi-Criteria Cloud Service Selection. In *5th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing*, pages 44-48.

Spence, R. (2014). Information visualization: An introduction, 3rd edition, *Springer*.

Wittern, E., Kuhlenkamp, J. and Menzel, M. (2012). Cloud Service Selection Based on Variability Modeling. *Service-Oriented Computing*, 127-141.

Yu, Z. and Zhang, L. (2014). QoS-aware SaaS Services Selection with Interval Numbers for Group User. *Journal of Software*. 553-559.

Zadeh, L.A. (1974). The concept of a linguistic variable and its application to Approximate Reasoning. *Learning systems and intelligent robots*, 1-10.