Quality of Web Mashups: A Systematic Mapping Study

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Abstract. Web mashups are a new generation of applications based on the composition of ready-to-use, heterogeneous components. They are gaining momentum thanks to their lightweight composition approach, which represents a new opportunity for companies to leverage on past investments in SOA, Web services, and public APIs. Although several studies are emerging in order to address mashup development, no systematic mapping studies have been reported on how quality issues are being addressed. This paper reports a systematic mapping study on *which* and *how* the quality of Web mashups has been addressed and how the product quality-aware approaches have been defined and validated. The aim of this study is to provide a background in which to appropriately develop future research activities. A total of 38 research papers have been included from an initial set of 187 papers. Our results provided some findings regarding how the most relevant product quality characteristics have been addressed in different artifacts and stages of the development process. They have also been useful to detect some research gaps, such as the need of more controlled experiments and more quality-aware mashup development proposals for other characteristics which being important for the Web domain have been neglected such as *Usability* and *Reliability*.

Keywords: Web Mashups, Product Quality, Systematic Mapping Study.

1 Introduction

Mashups are a new generation of Web applications that combine disparate Web services, RSS, ATOM feeds and other data sources, to produce new applications. Emerging technologies (e.g., Web services, User Interface widget libraries) and specific composition tools (e.g., Yahoo Pipes, Microsoft Popfly) have significantly simplified the access and reuse of such building blocks, leading to a component-oriented paradigm which represents a new opportunity for companies to leverage on past investments in SOA, Web services, and public APIs [4].

The challenge of developing Web mashups has motivated the appearance of a variety of techniques, methods and tools to address their composition process. However, some issues are still largely unexplored such as specific quality issues for this type of Web applications [5]. Although being mashups a type of Web

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applications, methods so far proposed for traditional Web applications need to be repurposed to capture the salient characteristics.

As far as we know, no evidence-based studies (e.g., systematic mapping studies, systematic literature reviews) have been reported on how product quality issues are being addressed for mashups. In this paper, we present a systematic mapping study for summarizing *which* and *how* product quality issues of Web mashups have been addressed by existing literature. A systematic mapping study is a means of categorizing and summarizing the existing information about a research question in an unbiased manner [12]. The goal of our study is, therefore, to address *which/how product quality issues are being addressed in Web mashup development* and *how the product quality-aware approaches have been defined and validated*.

This paper is organized as follows. Section 2 discusses related work. Section 3 presents the protocol we defined, employed and validated to conduct the systematic mapping study. Section 4 describes the results obtained. Section 5 discusses the threats to the validity of the results. Finally, section 6 presents our conclusions and suggests areas for further investigation.

2 Related Work

A number of surveys and reviews aimed at analyzing current mashup development approaches and tools have been reported in recent years (e.g., [2, 9, 10, 14]).

Hoyer and Fischer [10] presented a market overview of the different mashup composition tools by classifying and evaluating them according to several perspectives such as general information, functionality and usability. They classified more than 30 tools in their proposed classification model in order to draw market trends in context of Enterprise mashups. However, the evaluated quality aspects were related to the process development rather than the product quality of the generated mashups.

Beemer and Green [2] presented a comprehensive review based on 60 publications that helps researchers to classify the general research topics on mashups. A generic taxonomy was defined according to six categories: access control, integration, agents, frameworks, end-user programming and Enterprise mashups. Although a review methodology was establish and conducted, quality issues of mashups were not identified as a specific research topic.

Grammel and Storey [9] presented an overview of End-User development support in a selected set of mashup development environments. They explored, summarized and compared their features across six different issues: levels of abstraction, learning support, community support, discoverability, user interface design and software engineering techniques. Results showed there is still much room for further improvement. Again, the authors did not discuss the quality of mashups from the product perspective.

Orange Labs [14] presented a survey aimed at evaluating existing composer tools for mashups as well as at refining the design requirements for developing these tools. This work points explicitly the need of quality evaluation approaches, since as it was pointed out in [1] in 2009, 62% of CIOs were seeing mashups as not as reliable as traditional Web solutions and not adapted to enterprises.

Although several related surveys and reviews have been reported, they present two main limitations:

a) There is a need of a more systematic way in order to summarize the existing knowledge in this area, since the majority of these studies are informal literature surveys with no defined research questions, no search process, no defined data extraction or data analysis process.
b) There is a need of surveys or reviews specifically focused on the product quality of Web mashups. We are aware about several studies that address quality issues on Web mashups such as [3, 16, 17]. However, as far as we know, no empirical evidence-based studies have been reported in order to categorizing and summarize these studies.

3 Research Method

A systematic mapping study is a means of categorizing and summarizing all available research that is relevant to a particular research question, topic area, or phenomenon of interest [12]. It aims at presenting a fair evaluation of a research topic by using a trustworthy, rigorous, and auditable methodology. This research method has gained popularity in last years and it has been adopted in several other studies within the Web Engineering field [7, 8, 18].

A systematic mapping study involves several stages and activities. In the *planning* stage, the need for the mapping is identified, the research questions are specified, and the mapping protocol is defined. In the *conducting* stage, the primary studies are selected, the quality assessment used to discover representative studies is defined, the data extraction and monitoring is performed, and the obtained data is synthesized. Finally, in the *reporting* stage, the dissemination mechanisms are specified, and the mapping results are presented. The activities concerning the *planning* and the *conducting* of our systematic mapping are described in the following subsections. The *reporting* stage is presented in Section 4.

3.1 Research Question

We have carried out a systematic mapping study by considering the guidelines suggested in [12, 15]. The goal of our study is to examine which and how product quality aspects of mashups have been addressed from the point of view of the following research questions: a) RQ1: *Which/how product quality issues are being addressed in Web mashup development? and* b) RQ2: *How have the product quality-aware approaches been defined and validated?*. We focused on these research questions since they are tailored to identify which quality characteristics have been the most studied, how these characteristics are related to mashup development dimensions (i.e., stages and artifacts), and how quality-aware techniques by using these characteristics have been defined and validated. In addition, these research questions will allow us to summarize the current knowledge about product quality of Web mashups and to identify gaps in current research in order to suggest areas for further investigation.

3.2 Identifying and Selecting Primary Studies

The main sources we used to search for primary studies were IEEE Xplore and ACM digital libraries. In addition, we have manually searched in the proceedings of the following journals, books and conferences:

- Journal of Web Engineering (JWE).
- ACM Transactions on the Web (ACMTWEB).
- Foundations of Popfly: Rapid Mashup Development (Book).
- World Wide Web conference (WWW).
- International Conference on Web Engineering (ICWE).
- International Conference on Information Integration and Web-Based Applications & Services (iiWAS).
- International Conference on Service Oriented Computing (ICSOC).
- International Workshop on Web APIs and Service Mashups (MASHUPS).

The search string defined for retrieving studies is as follows: "(*web* OR *internet* OR *www*) AND (*mash*) AND quality"*. The asterisk symbol '*' signifies any character whose purpose it is to include any word variation of each search term (e.g., the search term 'mash*' includes the following words: *mashup* OR *mashing* OR *mash-Up* OR *mash* OR . . .)

We experimented with several search strings and this one retrieved the greatest amount of relevant papers. This search string was used in the IEEE Xplore and the ACM digital libraries as well as used in the screening of the other sources that were inspected manually. The period covered was the last 7 years, i.e., studies published from 2006 to 2012. This starting date was selected because, after following up the references of the preliminary retrieved studies, we realized that 2006 was the year in which the term "mashup" has started to appear in the Web Engineering field.

3.3 Inclusion and Exclusion Criteria

Each identified study was evaluated by the researchers conducting the systematic mapping study to decide whether or not it should be included. The discrepancies were solved by consensus. The studies that met the both following conditions were included:

- Studies presenting a method and/or technique to assist designers in the quality evaluation of Web mashups from the product perspective.
- Full papers.

The studies that met at least one of the following conditions were excluded:

- Introductory papers for special issues, books and workshops.
- Duplicate reports of the same study in different sources.
- Short papers with less than five pages.
- Papers not written in English.

3.4 Quality Assessment

In addition to general inclusion/exclusion criteria, it is considered critical to assess the "quality" of the primary studies. A three point Likert-scale questionnaire was used to

provide a quality assessment of the selected studies. The questionnaire contained the following questions: a) *Does the study present a method and/or technique for assessing the quality of mashups from the product quality perspective? (agree, disagree);* b) *Has the study been published in a relevant journal or conference? (e.g. CORE ranking, JCR list); and* c) *Has the study been cited by other authors? (Google Scholar).*

The score for each closed-question will be the arithmetic mean of all the individual scores from each reviewer. The sum of the three closed-question score of each study provides a final score which was not used to exclude papers from the systematic mapping study but was rather used to detect representative studies.

3.5 Data Extraction Strategy

The data extraction strategy was defined by breaking down each research question into more specific criterion in which a set of possible options was established. Table 1 shows this breaking down which is intended to make easier the data extraction and paper categorization. In addition, the rationale for each criterion is explained below.

Table 1. Data extraction strategy

Research questions	Criteria	Options
RQ1: Which/how the quality of Web mashups has been addressed?	C1: Product quality characteristics addressed in the studies	a) Functional suitability b) Performance efficiency c) Compatibility d) Usability e) Reliability f) Security g) Maintainability h) Portability
	C2: Stages based on the mashup development process	a) Component Selection b) Mashup composition c) Mashup usage
	C3: Artifacts involved	a) Conceptual models b) Source code c) Final user interfaces d) Components
RQ2: How have the product quality-aware approaches been defined and validated?	C4: Type of approach	a) New b) Extension
	C5: Type of validation	a) Survey b) Case Study c) Experiment d) No validation
	C6: Approach usage	a) Industry b) Academy

With regard to the criterion C1, a paper can be classified in one or more quality characteristics from the ISO/IEC 25010 standard SQuaRE [11]. We employed this standard since it proposes an updated product quality model which has been defined by consensus among experts.

With regard to the criterion C2, a paper can be classified in one or more stages based on the mashup development process proposed in [3]: *Component selection*, if the quality of the mashup is evaluated when components are being selected to create the mashup; *Mashup composition*, if the quality of the mashup is evaluated during the composition stage; and *Mashup usage*, if the quality of the mashup is evaluated once it has been completely defined.

With regard to the criterion C3, a paper can be classified in one or more artifacts: *conceptual models*, if the quality of mashups is evaluated on the intermediate artifacts that are created during the mashup development process (internal quality); *Source code*, if the quality of the mashup are assessed by inspecting the final implementation (external quality), *Final user interfaces*, if the quality of the mashup is assessed by inspecting the user interfaces, and *Components*, if the quality of selected components is evaluated/considered before mashing them.

With regard to the criterion C4, a paper can be classified in one of the following answers: *New*, if it presents an approach from scratch (i.e., an evaluation or technique specifically defined for assessing the quality of mashups); or *Existing*, if it presents an extension of a previous approach (e.g., a technique defined for assessing the quality of Web services that has been applied to evaluate mashups).

With regard to the criterion C5, a paper can be classified in one of the following types of strategies that can be carried out depending on the purpose of the validation and the conditions for empirical investigation [6]: *Survey*, if it provides an investigation performed in retrospect; *Case study*, if it provides an observational study in which data is collected during real/simulated environments; *Controlled experiment*, if it provides a formal, rigorous, and controlled investigation that is based on verifying hypotheses; and *No validation*, if it does not provide any empirical study related to the product quality for mashups.

Finally, with regard to the criterion C6, a paper can be classified according to the context/environment in which the quality evaluation method/technique has been defined or are being used currently (industrial context and/or academic context).

3.6 Synthesis Methods

We applied both quantitative and qualitative synthesis methods. The quantitative synthesis was based on:

- Counting the primary studies that are classified in each answer from our criteria.
- Defining bubble plots in order to report the frequencies of combining the results from different research sub-questions. A bubble plot is basically two x–y scatter plots with bubbles in category intersections. This is useful to provide a map and giving a quick overview of a research field [15].
- Counting the number of papers found in each bibliographic source per year.

The qualitative synthesis is based on including several representative studies for each criterion by considering the results from the quality assessment.

3.7 Conducting the Review

The search to identify primary studies in the IEEE Xplore and ACM digital libraries was conducted on the 29th of December 2012. The application of the review protocol yielded the following results:

- The bibliographic database search identified 80 potentially relevant publications (46 from the IEEE Xplore and 34 from the ACM digital library). After applying the inclusion and exclusion criteria documented in Section 3.3, 29 publications were finally selected (13 from IEEE Xplore and 16 from ACM digital library).
- The manual bibliographic review of the other sources identified another 107 potentially relevant publications. After applying the inclusion and exclusion criteria, the following publications were finally selected: 9 papers (2 from WWW, 0 from ICWE, 1 from WISE, 1 from iiWAS, 1 from SOSE, 2 from ICSOC, and 2 from MASHUPS).

Therefore, a total of 38 research papers were selected by our inclusion/exclusion criteria. Some studies had been published in more than one journal/conference. In this case, we selected only the most complete version of the study.

4 Results

A summary of the results of our study is presented in Table 2. The included papers which are cited in this section as [SXX] are referred to Annex A. The full list of papers included in our systematic mapping study is available at `http://www.dsic.upv.es/~afernandez/resources/qwe13`.

With regard to the criterion C1 "Product quality characteristics addressed in the studies", results indicate that the most addressed quality attributes were *Performance efficiency* (63%) and *Security* (47%). The rationale is because of the data-intensive nature of mashups where quick and secure access is typically required. The less considered attributes were *Portability* (10%), *Maintainability* (21%), and *Compatibility* (10%). This is in line with some claims stated by other researchers such as *"Quality aspects such as maintainability or scalability play a minor role because the final Mashup is needed only for a short time"* [S04]. Although *Functional suitability* (42%) and *Reliability* (42%) received less consideration than we expected, we were surprised that *Usability* just account the of the 23% studies since this quality characteristic has usually been claimed as one of the most relevant in the Web domain.

With regard to the criterion C2 "*Stages based on the mashup development process*", results indicate that the majority of the studies agree to address quality issues when the mashup is being composed (55%). These studies are aimed at improving the composition process in order to obtain a mashup with better quality. For instance, in [S01] is presented a composition technique based on pipelines in order to improve the *Functional suitability* and *Performance* of the mashup obtained.

Table 2. Results of the systematic mapping

Criteria	Possible answers	# Studies	% Percentage
C1: Product quality characteristics addressed in the studies	Functional suitability	16	42.11
	Performance efficiency	24	63.16
	Compatibility	4	10.53
	Usability	9	23.68
	Reliability	16	42.11
	Security	18	47.37
	Maintainability	8	21.05
	Portability	4	10.53
C2: Stages based on the mashup development process	Component selection	14	36.84
	Mashup composition	21	55.26
	Mashup usage	16	42.11
C3: Artifacts involved	Conceptual models	8	21.05
	Source code	13	34.21
	Final user interfaces	9	23.68
	Components	15	39.47
C4: Type of approach	New	29	76.32
	Extension	9	23.68
C5: Type of validation	Survey	1	2.63
	Case Study	18	47.37
	Experiment	9	23.68
	No validation	11	28.95
C6: Approach usage	Industry	15	39.47
	Academy	33	86.84

The 42% of the papers focused on how to improve the quality when the mashup is completed. Some of these studies such as [S08], are aimed at offering recommendations to previous stages of the development process; whereas others studies such as [S05] are aimed at evaluating the quality in use to report problems. Finally, fewer studies considered the component selection stage to address quality issues (37%). We argue that more papers such as [S03] are needed in order to provide methods or guidelines to select the proper components which lead to a better mashup.

With regard to the criterion C3 "*Artifacts involved*", results indicate that the majority of the studies addressed quality issues at components selected to be mashed (40%). An example can be found in [S03] where components are previously rated in order to assist the evaluation of the obtained mashup. The 34% of the studies showed quality issues at source code of the mashup. An example can be found in [S10], where an algorithm analyses the source code in order to improve efficiency issues. Fewer studies considered the conceptual models (10%) that define the component composition in order to improve quality issues. We found an example of this kind of studies in [S02], where orchestration and business models are analyzed to improve the mashup acceptance. Finally, the 23% of the studies analyzed the interaction of the

mashup in order to discover deficiencies, such as for example in [S06], where areas for defining metrics were explored.

With regard to the criterion C4 "*Type of approach*", results indicate that the majority of the papers (76%) presented new approaches to deal with quality issues on Web mashups. Some of these studies such as [S07], proposed ideas from scratch or inspired in other domains. We argue that this finding shows an agreement among authors in the importance of considering Web mashups not only as simple Web applications.

With regard to the criterion C5 "*Type of Validation*", results indicate that the majority of the studies have presented *Case studies* in order to validate their approaches (47%). This is an encouraged result since it improves the situation described in a systematic review presented in [13] which stated a lack of rigorous empirical studies for Web Engineering research. An example of case study can be found in [S12]. However, fewer *Experiments* have been conducted (23%). Experiments should be more employed since they provide a high level of control and are useful for evaluating approaches in a more rigorous way. An example of experiment can be found in [S09]. Finally, surveys are the less preferred study for other researchers (3%) and the rest of the papers (29%) did not provide any kind of validation or they just described proof of concepts.

With regard to the criterion C6 "*Approach usage*", results indicate that the majority of the studies (87%) have been performed from the academic research viewpoint, for instance in [S08]. However, it is also important to note that a worthy 39% of the studies were performed from the industry research viewpoint. These studies, such as [S11], were especially interested at addressing security issues, which have been detected as relevant for practitioners.

It is worthy to mention that the analysis of the number of research studies on quality issues for mashups showed that there has been a growth of interest on this topic since 2007. Figure 1 shows the number of selected publications by year and source. We believe that this growing interest supports the relevance of conducting evidence-based studies in this area.

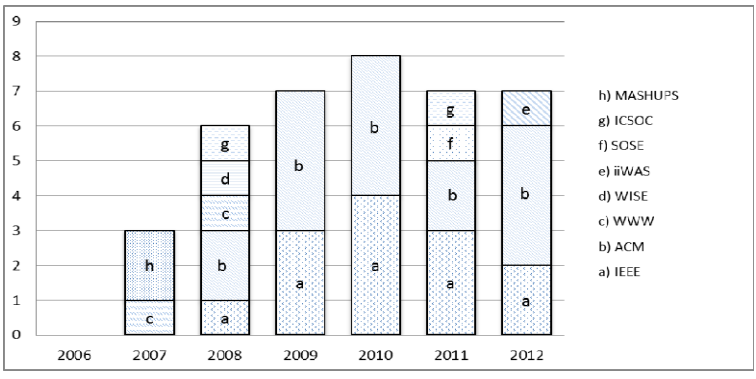

Fig. 1. Number of publications by year and source

The criteria were combined to establish a mapping with the aim of providing an overview of quality issues for mashups. This mapping allows us to obtain more information about how the results from each criterion are related to the others, and what the possible research gaps are. Due to space reasons, Figure 2 only shows one of the bubble plots which is related to compared the criterion C1 *"quality characteristics addressed"* against the C2 *"phases"* and C5 *"type of validation"*. Other bubble plots are available at `http://www.dsic.upv.es/~afernandez/resources/qwe13.`

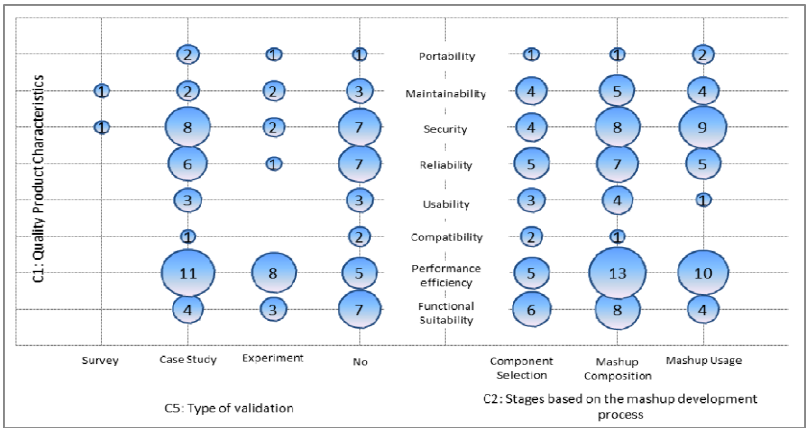

Fig. 2. Mapping results obtained from the combination of C1 against C2 and C5

The mapping results confirm that most important stage for all the quality characteristics is the Mashup Composition. However, it shows research gaps such as relevant quality characteristic have not been validated through controlled experiments (e.g., *Security*, *Usability*, *Reliability*) and other characteristics which are important for the Web domain have been neglected (e.g. *Usability*, *Reliability*).

5 Threats to Validity

The main limitations of this study are the scope of our research questions, publication and selection bias, inaccuracy in data extraction, and misclassification.

The scope of our research question was limited to the product quality of the mashups. However, we realized during the conduction of this mapping that quality of the development process is an interesting extension which will be explored as further work.

Publication bias refers to the problem that positive results are more likely to be published than negative results [12]. We are aware about this inherent limitation to our bibliographic sources. With regard to publication selection bias, we chose the sources where papers about mashup development are normally published, and we compared the retrieved papers against a small sample which was previously identified as relevant papers to appear. However, we did not consider some other bibliographic sources such as SpringerLink or ScienceDirect that may have affected the

completeness of our systematic mapping. Moreover, since our bibliographical search was conducted at the end of 2012, some papers not yet indexed in this last period were not considered.

Finally, we attempted to alleviate the threats of inaccuracy in data extraction and misclassification by conducting the classifications of the papers with three reviewers and solving the appeared discrepancies by consensus.

6 Conclusions and Further Work

This paper has presented a systematic mapping study in order to address *which/how product quality issues are being addressed in Web mashup development*, and *how have the product quality-aware approaches been defined and validated*. The principal findings of our study are:

- Some quality characteristics which we consider relevant in the Web domain (i.e., *Functional suitability* and *Usability*) have been paid less attention than others.
- There is a shortage of approaches in order to provide methods or guidelines to select the proper components which lead to better mashups.
- The majority of quality issues are addressed at the mashup composition stage. However, quality-aware approaches dealing with conceptual models are gaining presence, which is relevant since quality issues can be addressed at earlier stages of the mashup development process.
- There is a shortage of controlled experiments provide evidence, in a more rigorous way, about the existing quality evaluation methods/techniques for mashups.

Our results also confirmed some claims stated by other researchers according to the most relevant quality characteristics such as *Performance efficiency* and *Security*. In addition, they have been useful to detect some research gaps, such as the need of more empirical studies, especially controlled experiments involving quality characteristics such as *Security*, *Usability*, *Reliability*; and the need of more quality-aware mashup development proposals for other characteristics which being important for the Web domain have been neglected in the mashup development (e.g. *Usability*, *Reliability*).

Although our findings may be indicative of the field, further work is needed to confirm the results obtained. This further work will include the extension of this systematic mapping by a) including other sources (e.g., SpringerLink, Science Direct), b) identify and including quality issues for the mashup development process itself, c) including compositionality issues, and d) analyzing the rigor of the empirical studies proposed through a systematic review addressing more specific research questions. We are also intended to address some of the research gaps discovered. For instance, addressing usability definition and evaluation of mashups through a usability model tailored to the salient and specific characteristics of them.

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Annex A: Excerpt of the Papers Selected

Complete list available at: `http://www.dsic.upv.es/~afernandez/resources/qwe13`

S01. Biörnstad, B., Pautasso, C.: Let It Flow: Building Mashups with Data Processing Pipelines, International Conference on Service-Oriented Computing (ICSOC 2007), pp. 15–28 (2009).

S02. Bozzon, A., Brambilla, M., Facca, F., Carughu, G.: A Conceptual Modeling Approach to Business Service Mashup Development. 7th International Conference on Web Services, (ICWS 2009), pp. 751–758 (2009).

S03. Cappiello, C., Daniel, F., Matera, M.: A Quality Model for Mashup Components, 9th International Conference on Web Engineering (ICWE 2009), pp. 236-250 (2009).

S04. Cappiello, C., Daniel, F., Matera, M., Pautasso, C.: Information Quality in Mashups. IEEE Computer Society. 30–38 (2010).

S05. Jackson, C., Wang, H.: Subspace: secure cross-domain communication for web mashups. 16th International World Wide Web Conference (WWW 2007). pp. 611–620 (2007).

S06. Koschmider, A., Hoyer, V., Giessmann, A.: Quality metrics for mashups. Annual Research Conference of the South African Institute of Computer Scientists and Information Technologists. pp. 376–380 (2010).

S07. López, J., Bellas, F., Pan, A., Montoto, P.: A Component-Based Approach for Engineering Enterprise Mashups. International Conference on Web Engineering (ICWE 2009). pp. 30–44 (2009).

S08. Olsina, L., Lew, P., Dieser, A., Rivera, B.: Updating quality models for evaluating new generation web applications. J. Web Eng. 11, 3, 209–246 (2012).

S09. Riabov, A. V, Boillet, E., Feblowitz, M.D., Liu, Z., Ranganathan, A.: Wishful search: interactive composition of data mashups, 17th International World Wide Web Conference (WWW 2008), pp. 775–784 (2008).

S10. Roy Chowdhury, S., Daniel, F., Casati, F.: Efficient, Interactive Recommendation of Mashup Composition Knowledge. 11th International Conference Service-Oriented Computing (ICSOC 2011), pp. 374–388 (2011).

S11. Dos Santos, C.R.P., Bezerra, R.S., Granville, L.Z., Bertholdo, L.M., Cheng, W., Anerousis, N.: A data confidentiality architecture for developing management mashups. International Symposium on Integrated Network Management, pp. 49–56 (2011).

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