Semantic Web User Interfaces: A Systematic Mapping Study and Review

Ghislain Hachey Dragan Gašević

July 30, 2012

Abstract

Context: Exploration of user interfaces has attracted a considerable attention in Semantic Web research in the last several years. However, the overall impact of these research efforts and the level of the maturity of their results are still unclear.

Objective: This study aims at surveying existing research on Semantic Web user interfaces in order to synthesise their results, assess the level of the maturity of the research results, and identify needs for future research.

Method: This paper reports the results of a systematic literature review and mapping study on Semantic Web user interfaces published between 2003 and 2011. After collecting a corpus of 87 papers, the collected papers are analysed through four main dimensions: general information such as sources, types and time of publication; covered research topics; quality of evaluations; and finally, used research methods and reported rigour of their use.

Results: Based on only the obtained data, the paper provides a high level overview of the works reviewed, a detailed quality assessment of papers involving human subjects and a discussion of the identified gaps in the analysed papers and draws promising venues for future research.

Conclusion: We arrive at two main conclusions: important gaps exist which hinder a wide adoption of Semantic Web technologies (e.g. lack user interfaces based on semantic technologies for social and mobile applications) and experimental research hardly used any proven theories and instruments specifically designed for investigating technology acceptance.

1 Introduction

For the success of the Semantic Web vision, research on novel user interfaces is essential. This is especially important if the Semantic Web vision is considered in terms of its implementation as the Web of (Linked) Data. While it is promising to collect and interlink semantically relevant data from diverse sources, it is of equal importance to present and allow users to interact with that data effectively. The quality of user interfaces is essential if we are to show the users the real added value of the Semantic Web. This has already been recognised in the earlier days of the Semantic Web research, and many researchers have so far proposed many solutions addressing different tasks and target user groups [95].

To be able to evaluate the present state and maturity of the area, it is necessary to analyse the available research results. Although there has been some attempts to survey (some elements of) the Semantic Web user interface research [71, 95, 52], there has not been reported surveys that followed methods for systematic literature mapping studies [97, 67] and surveys [15, 37, 36, 35, 73]. A systematic mapping study provides a reproducible detailed picture of the covered research areas and gaps.

In this paper, we report on a systematic review and mapping study of the Semantic Web user interfaces topic. The applied method is described in detail in section 2. Based on the method, we first collected and then analysed the collected papers in order to understand the researched topic from various dimensions: general trends of the published work on the topic such as sources, types, and time of publication (subsection 3.1); covered research topics (subsection 3.2); quality of papers—those reporting findings on experimentation involving human participants (subsection 3.4); and finally, research methods used and their rigour (subsection 3.3). Based on the analysis of these four dimensions, the paper discusses (section 4) the gaps that emerge from the conducted analysis and discusses promising research directions—in terms of both topics and research methods.

2 Method

Recognising a need to systematically synthesise available research evidence, well-established evidence-based disciplines [113] such as medicine and education developed a research method called systematic literature review. This practice has recently been recognised in several computing disciplines of which software engineering is probably the most advanced discipline in adoption of this research method. Two recent ternary-studies (i.e., systematic reviews of systematic reviews) indicate a significant update of this research method in software engineering: [75] identified 53 systematic literature reviews published between January 1, 2004 and June 30, 2008; a follow-up study by [20] identified 67 systematic literature reviews in software engineering published between July 1, 2008 and December 31, 2009. More recently, software engineering research introduced a new method, spin-off of systematic literature reviews–systematic mapping studies. Such studies are more focused on developing classification schemes of a specific topic of interests (e.g., testing of software product lines [39] and reporting on frequencies of publications which cover a given topic of the development classification schemes. Mapping studies are typically used to give a general overview of a studied area, and are typically done before conducting a systematic literature review.

In this paper, we decided to report the findings of a study that was conducted by combining the methods for systematic literature mapping and review to investigate the current state of research of Semantic Web UIs. The methodology used for this paper is based on the model that was adapted by several others in the field of software engineering [37, 74, 36, 35, 15] for presenting literature reviews and also some other important elements that were defined in [101, 17]. Finally, we adopted the study mapping techniques found in [67, 97] and added novel elements to those techniques. The details of the followed research method are described in the following subsections.

2.1 Study Design

Here, we discuss the main focus and goals, point out the questions this review attempts to answer and clearly explain how we determined what research papers were included and excluded.

The ***focus*** of this literature review is a mixture of Cooper's *"research outcomes*'', *"research methods"* and *"practises or applications"* categories [17]. Our focus on *research outcomes* reveals gaps in the literature with regards to Semantic Web UIs. Our findings are based on the systematic analysis of a large collection of research material. *Research methods* are analysed to provide an overview of the state of approach evaluations used by researchers. This provides insight into the strengths and weaknesses of the Semantic Web UI literature. Our focus on *practises and applications* shows useful information regarding who provides Semantic Web UI prototypes and what are the *types*[1] of Semantic Web UI.

Our ***goal*** is to integrate outcomes and synthesise the results. We also attempt to generalise findings across our collected research papers and provide constructive criticism. Another important goal of this review is to identify central issues that in our opinion hinder a wider adoption of the Semantic Web and its slow rate of attracting an increasing number of scientists focusing on the Semantic Web UI—an essential aspect of the Semantic Web.

Finally, we identify a set of important ***questions*** to be answered with regard to the Semantic Web UIs.

- How is the effort distributed among various areas of the Semantic Web UI?
- What research methods have been used in evaluating Semantic Web UIs?

[1] We later define various categories of UIs (e.g. search, browse, edit...)

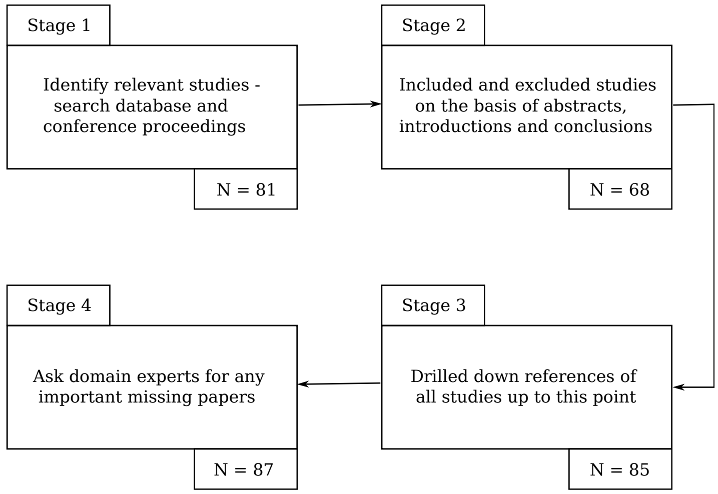

Figure 1: Study selection process

- How detailed are basic software engineering aspects (e.g. design or architecture)? In other words, would software developers be able to put into practice proposed solutions in the literature based on the guidance of researchers with regards to software development?
- What is the state of the intelligent UI aspects?
- What is the state of querying and searching interfaces?
- What is the state of visualising, browsing, and editing?
- What is the state of reviews and empirical analysis for the subject under study?

2.2 Data Collection

The data collection followed an iterative process: collecting research studies follows a slight variation of the two similar approaches adopted in [15, 35] and is illustrated in Figure 1.

Stage 1 consist of a ***database search*** through academic and state of the art publication databases. A number of relevant digital libraries were identified to be searched in a systematic manner:

- SpringerLink
- ACM Portal Digital Library
- ScienceDirect
- IEEE Xplore Digital Library

These databases are used as they are commonly used sources for conducting systematic surveys in computing research. The quality of the search engines is empirically validated for the purposes of conducting systematic reviews [28]. It is important to note that none of the libraries offered searching data using semantic web technologies. This is unfortunate but understandable considering that this field is still young and mostly a realm of research. Not all databases had the same features and search capabilities, an issue reported by others as well [15, 37]. However, we found that it *was* possible to conduct an equivalent of a desired Boolean search for all digital libraries. The *logical* Boolean search conducted is described below.

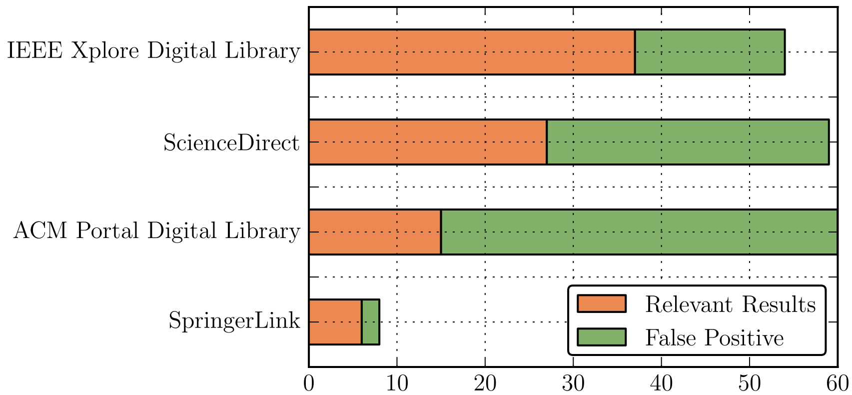

Figure 2: Searched Digital Libraries Relevant and False Positive Distribution

("semantic web" OR "linked data web" OR "web of data" OR
"web 3.0") AND ("user interface" OR "UI")

To conduct the equivalent of the above search string it was necessary to learn how each digital library's advanced search feature works. For example, both SpringerLink and IEEE supported the above search directly with minor syntax differences. A combination of 4 searches with various filters was needed to achieve the same *logical* search with ACM and ScienceDirect. Finally, in addition to the above string, we used filtering to only get papers from 2003 to October, 2011. The end result was that all papers retrieved had within their title, abstract or keywords the combination of the keywords semantic web (or "linked data web", "web of data" or "web 3.0") and user interface (or "UI").

The title and abstract of every paper were individually examined for false positives; that is, it was possible for a search result to contain all wanted keywords but without necessarily discussing a user interface for the semantic web. The stacked bar in Figure 2 shows the distribution of true and false positives for all searched digital libraries. At this stage, we had a total number of 81 studies to carry to the next stage.

Exclusion and inclusion criteria were outlined in *Stage 2* to filter out further irrelevant studies from *Stage 1* [2]:

- Discusses a semantic search engine but with a strong emphasis on the UI
- Discusses any aspect of software engineering for the Semantic Web UI
- Discusses new research challenges for UI (i.e. interface metaphors, intelligent UI assistant, meta-data visualisation, ontology visualisation)
- Discusses integration tools for the development of Semantic Web UI
- Discusses Semantic Web UI for high volume data (sensors, feeds, streams...)
- The paper "reviews" some aspects of the above criteria
- Only peer-reviewed and published material was included (exclusion criteria)
- If more than one paper was published on the same subject by the same author (i.e. follow up papers,) only the latest one was included. (exclusion criteria)

[2] the last two listed item below are the only exclusion criteria.

Bearing the above criteria in mind, we closely examined all titles, abstracts, introductions and conclusions of all collected papers from *Stage 1*. Sixty eight papers meeting all selection criteria outlined were kept and carried to *Stage 3*.

In *Stage 3*, we ***examined references*** for every paper that made it until this point. Only papers with a title clearly showing that a user interface for the semantic web was discussed were selected. This method was not as thorough as examining both titles *and* abstracts as in *Step 1 and 2*; as a result some relevant papers were possibly left out. Selected papers from references were downloaded, checked against the inclusion and exclusion criteria of *Stage 2*, accepted or rejected, and finally, had their own references examined as well as explained herein. We paid special attention to papers from main Semantic Web venues (e.g. ISWC, ESWC and Journal of Web Semantics). The process was repeated until all references examined would not yield any new relevant papers.

A total of 85 studies were carried to the final stage, *Stage 4*. The remaining came out of suggestions from expert researchers in the field (i.e. those with published papers in this review). Email was used to contact said researchers.

2.3 Data Analysis

A coding book (questionnaire) was used to extract data from the literature based on Cooper's data evaluation stage of conducting a literature review [17]. This was an iterative process. A first version of the coding book was designed and piloted. As we tested the coding book on a small subset of collected papers, more variables were brought to our attention. Also, the way we had organised our variables in the coding book changed during this iterative process. After several iteration of refinement we settled on a final format which was then used to code all collected papers.

Here we summarise the coding book and its main variables (the full version of the coding book is detailed in Appendix A).

1. *General Information for the Paper* - Recorded variables more general for each paper such as:
   (a) The year and type of publication.
   (b) Whether the paper collected only anecdotal evidence.
   (c) How the paper collected data.
   (d) Whether statistical analysis was used or not.
   (e) The research evaluation approach which we categorise following the scheme developed in [15], based on [107, 127, 46] and shown in Table 1.
2. *Quality Assessment Information* – For papers reporting findings on human participants we also provided a thorough quality assessment, as explained in subsection 2.4.
3. *Semantic Web and User Interfaces Specific Information* – Basic data specific to Semantic Web UI.
   (a) *Subject of Paper* - Papers were classified into one of several broad categories that we defined.
   (b) *UI Design, Framework and Architecture*
   (c) *Intelligent User Interface Aspects*
   (d) *Practical Applications* - The types of prototypes developed (if any) was coded.
   (e) *Querying and Search Interfaces*
   (f) *Visualising, Browsing and Editing*

Each coding book instance for a given paper was filed through a web-based application and the data was recorded in a database. A relational database was used mainly because of the availability and maturity of rapid application development frameworks not found with triple-stores or other RDF based databases. The application along with the corpus of references is also available for download at `www.sf.net/projects/semanticwebui` for anyone wishing to reproduce the review.

Table 1: Research Evaluation Categorising Scheme

Research Evaluation Category	Description
CS (Case study)	An empirical enquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used [125]
DC (Discussion)	Provided some qualitative, textual, opinion-oriented evaluation. e.g., compare and contrast, oral discussion of advantages and disadvantages [127]
EA (Example application)	Authors describing an application and provide an example to assist in the description, but the example is "used to validate" or "evaluate" as far as the authors suggest [107]
EP (Experience)	The result has been used on real examples, but not in the form of case studies or controlled experiments, the evidence of its use is collected informally or formally [107]
FE (Field experiment)	Controlled experiment performed in industry settings
LH (Experiment with human subjects)	Identification of precise relationships between variables in a designed controlled environment using human subjects and quantitative techniques
LS (Experiment with software subjects)	A laboratory experiment to compare the performance of newly proposed system with other existing systems [46]
SI (Simulation)	Execution of a system with artificial data, using a model of the real word

2.4 Quality Assessment Methodology

There are conflicting views about whether or not low quality papers should be included in a review [101]. We made the decision to include all papers which reported on experiments involving human participants regardless of the quality for a couple of reasons: there is not much literature on the subject under review and we think including all papers will provide a bigger, more detailed picture of the reviewed topic.

A quality assessment was provided on a subset of the papers—those reporting findings on human participants. As stated in [73], advantages of providing a good quality assessment are:

- To investigate whether quality differences provide an explanation for differences in study results.
- As a means of weighting the importance of individual studies when results are being synthesised.
- To guide the interpretation of findings and determine the strength of inferences.
- To guide recommendations for further research.

Quality assessment will be based on 11 criteria (detailed in subsection A.3) which were developed in [36, 35] and adopted in [15]: these quality assessment criteria are based on the Critical Appraisal Skills Programme (CASP) [115] and we further tuned it to better reflect our research on the Semantic Web UI.

We followed the same approach as [15] and used a ternary scale ("Yes", "Partial" or "No") to grade the reviewed studies on each of the quality assessment criteria: answers were quantified by assigning values of 1 to "Yes", 0.5 to "Partial" and 0 to "No". However, we had a more refined and repeatable grading process for each quality criteria: if the authors addressed most questions to consider (>80%), we graded "Yes"; if only some were addressed (<80% and >10%), we graded "Partial"; and, if nearly none were addressed (<10%), we graded "No".

A paper was first coded by both authors independently. The results were then shared to check for any differences and improve the mutual understanding of the coding instrument. This process was done until a high level of agreement was reached (i.e. >90%). All remaining papers were finally coded by the first author.

3 Results

The results are presented in a logical order. Descriptive text, tables and various charts are used when deemed appropriate. Consolidated data on questions with only one possible answer yielded a consistent total of 87 papers (or 100%) in a given table—for those, the total sum was included. Note that adding rounded values causes sums to not always equal exactly 100%. On the other hand, it made no sense to include summations in tables consolidating data on questions with one *or more* possible answers.

3.1 General Overview

Most papers surveyed were conference proceedings publications with 52.32% of all papers reviewed in this study and 26.75% journal articles (more detailed breakdown in Table 2). There was very few secondary research—in fact, only three reviews—and no systematic or mapping studies at all. This clearly shows the need and importance of this paper.

The distribution of papers collected over the defined period of 2003 to 2011 was relatively evenly distributed with two minor exceptions (see Table 3): there were less papers in the early years (i.e. 2003 and 2004) and the years 2006 and 2008 had a few more papers. The former can be explained by the fact that the Semantic Web research was just starting at that time and focuses were more about core ideas and concepts than UIs for the semantic web.

Most reviewed studies came out of Europe with 58.14% followed by Asia-Pacific and North America with 22.09% and 17.44% respectively while South or Central America contributed 2.33%.

Table 2: Publication Types

Publication Type	**Numbers**	**Percentages (%)**
Conference full research paper	15	17.44%
Conference preliminary or work in progress	30	34.88%
Conference survey	1	1.16%
Conference tool demo	8	9.30%
Conference workshop	9	10.47%
Journal original research	20	23.26%
Journal survey	3	3.49%
SUM	86	100.00%

Table 3: Year of Publications

Publication Year	**Numbers**	**Percentages (%)**
2003	3	3.49
2004	4	4.65
2005	9	10.47
2006	14	16.28
2007	11	12.79
2008	14	16.28
2009	10	11.63
2010	11	12.79
2011	10	11.63
SUM	86	100.01%

3.2 Semantic Web and User Interfaces Specific Information

In this subsection, we report on the specific categories of research results as determined by our analysis. We generally analysed the papers from several aspects: primary subject of paper, software engineering aspects proposed for development of Semantic Web UIs; intelligent Semantic Web UI; querying and search in/for Semantic Web UI; visualisation, browsing and editing approaches for the Semantic Web UI.

3.2.1 Software Engineering for development of Semantic Web UIs

A total of 40 papers discussed in some way the *design* of a semantic web UI; they can be classified in several broad categories: integrated UI design for various device types was discussed in [51, 111]; the design of UI automatic assembly was a relatively popular area [18, 56, 84, 70, 55, 59]; only one paper discussed the design of some novel algorithm tightly related to the UI [79]; [124] discussed the design for adaptive UIs; [23, 93, 43, 122] made use of ontologies for the logical design of UIs, and [94] made use of ontologies to integrate applications at the UI level; and finally, several discussed the design of semantic wikis [104, 9, 118] and browsers [100, 54, 3]. Many papers merely discussed design principals, decisions and issues in general [106, 121, 41, 98, 114, 31, 13] without getting too much in the specifics of software design.

The *automatic generation of UI elements* was discussed in 24 papers in which variety of methods was explored: some data mash-up tools experimented with the automatic display and re-display information in various ways [58, 61]; the automatic generation of all or some elements of web pages (e.g. query interface or graph node presentation) is discussed in [84, 70, 44, 34, 6, 111, 43, 59, 56]; generation of UIs based on WSDL [51] or SOA [6] with semantic technologies; generation of UIs based on RDF schema or ontologies is discussed in [18, 44, 93, 13, 122], and some combined Model-Driven Development with ontologies for automatic UI adaptation [84, 80]; [50] discusses UI generation based on a novel UI language; and finally, [38, 55] explored personalising UI generation.

A total of 15 papers discussed a *framework* of some sort which can be classified in several broad categories: framework for ontology building [85]; framework to deploy semantic applications [106, 59]; framework to generate adaptive and personalised UIs [51, 96, 102, 124, 93, 55, 80]; application specific frameworks (e.g adaptive e-learning system or on-line shopping) [87, 34, 13]; framework to provide a solution to the lack of NLIs, automatic service discovery, and large number of query-driven websites [120]; and framework to separate the data from presentation [50].

More than half of all papers reviewed a software *architecture*: some discussed high level architectures, but little about the UI part [82, 87, 98, 91, 23, 38]; most were application specific architectures [58, 45, 18, 110, 77, 14, 121, 41, 63, 114, 34, 31, 108, 90, 109, 84, 83, 62, 86, 80, 81, 119] and framework architectures [48, 94, 124, 93, 50, 59]; semantic service oriented architectures were discussed in [99, 6, 16]; [123] proposed an architecture for adaptive UIs; [111] proposed an architecture for constraint-based graph visualisation on mobile phones; semantic browsers (or browsing tools) architectures can be found in [106, 33, 3] and a visualising tool architecture in [42]; and, semantic wikis architectures are presented in [10, 104, 9, 118].

3.2.2 Intelligent UI Semantic Web UI

Personalisation on the semantic web has been discussed in a number of interesting ways: [70, 58, 91] discussed how users can browse, view, and navigate information in their own ways without being constrained to a rigid UI; Semantic Web personalisation systems to tailor information services to the users was evaluated in [124, 110, 87, 48, 93]; [96, 38, 102, 55] explored the personalisation of the UI itself based on semantic data; personalisation through user annotation is discussed in [109]; and more traditional and basic personalisation (i.e. bookmarks and other traditional features of browsers) is discussed in [100].

Localisation of content and UI was barely explored at all: [45] discusses a content-based image retrieval (CBIR) system with support for multi-lingual querying; [22] discusses a semantic knowledge based that is multilingual but they don't explain how this was achieved; [57] discusses a multilingual museum knowledge base; the Semantic Wikipedia is multilingual [118]; and finally, [59] discusses their early attempt at internationalisation but admit it is difficult to achieve when automatically generating the UI at run-time. Contextualisation was only discussed in [40, 55].

Most papers discussing some form of intelligent UI provided guidance to users through suggestions and auto-completion mechanisms [5, 34, 108, 9, 57, 4]. The others explored user assistance mechanisms such as using intelligent work-flows [79, 77, 40, 24], basic integrated help documentation [45], interpreting and gathering information in a semantic fashion [33], or through seamless technology integration at the UI level [31].

3.2.3 Querying and Search for/in Semantic Web UIs

Of all papers claiming support for SPARQL, most mention that the SPARQL language is used for search and/or navigation [87, 103, 104, 121, 102, 31, 54, 118, 3], but provide no useful information as to how it all ties into a GUI. Others make available SPARQL end points to query their knowledge base [53, 128], and the GUI itself uses SPARQL while remaining transparent to the user (e.g. faceted browsing). Custom UI specifically for SPARQL query generation are explored in [86, 88, 63, 79, 29, 18], one of which can translate to SPARQL even when users are not aware of the underlying schema [79], and yet another can use SPARQL to help build the GUI [18]. In [9, 90], SPARQL is embedded into the web pages. Finally, SPARQL generated from natural language input UIs is studied in [72, 119, 4].

A smaller number of papers explored less commonly used query languages, but sometimes in more interesting and exploratory ways. For instance, [43] used IBM's query language; the interesting part is that the querying is done through a graph UI prioritising ease of use over expressive power. [34] follows a similar approach: their visual query tool called "Lois" executes queries in a language called OCML. [41] built a query-by-example-style graphical interface for the user to query data which then translates to F-Logic queries—it's not clear what the UI looks like, how it works, and how it translates to F-Logic queries, however. The query language used to formulate queries over MPEG-7 description (i.e. the MPEG Query Format (MPQF) [32]) is used in [45] with a good overview of the associated GUI. Basic DL-based syntax is used [85, 80]; it is not clear how the GUI actions translate to queries in [85], and [80] uses ontologies to derive UIs which then translate to queries. RDQL was used in [14, 106], but it does not talk about how or if it links to the UI. The natural language input interface to RDQL querying language is explored in [5].

A little more than a few papers evaluated custom querying languages. [18] can take SPARQL queries but they are translated to S3QL [1]. S3QL is used for insertion, deletion, and updating of data. The GUI is assembled through a S3QL query, a process clearly detailed in the paper. [56] demonstrates a facet UI that translates to custom code from a built-in module of SWI-Prolog and [59] supports filtering through a custom language extension—both have future plans of supporting querying anything with SPARQL end-points eventually (at the time of their writing). The querying language used in [120] is SOBL—a declarative service querying language. SOBL (Semantic Object Behaviour Language) is an extension of the SNL (Structured Natural Language). Sparqlets, the RDF-enabled widgets used in [91], and related server-side routines are programmed in SPARQL+ and SPARQLScript. SPARQL+ extends SPARQL's standard syntax with query aggregates and basic update functionality. SPARQLScript combines SPARQL+ with placeholders, variable assignments, control structures, queries across multiple endpoints, and result templating. A unique approach is used in [81]: the querying of the data from the UI goes through a semantic layer in the architecture. First the ontology model CIDOC CRM Model (artifacts reference model), then the schema mapping and finally a custom query reformulation that can query disparate and heterogeneous data sources. In [68] the authors present ACE—a logic language and a knowledge representation language which could play the role of both OWL and SPARQL, for example. They only briefly discuss how a UI to ACE would be easier done than a UI to OWL. Finally, [109] discussed custom querying but with no explicit explanations of how it ties with the GUI.

3.2.4 Visualisation, Browsing and Editing in/for Semantic Web UIs

Evaluations of visualisation (e.g. graph visualisation, 3D visualisation and interactive visualisation) of semantic data and/or schema can be found in [14, 42, 54, 111, 43, 27, 59]. Only a couple of papers were found to discuss browsing of RDF data without hiding the technical details [111, 42] while many more discussed browsing of RDF data but hiding the technical details [53, 58, 106, 18, 33, 61, 100, 56, 22, 54, 70, 86, 59, 3].

Table 4: How Many Participants

Participants	**Numbers**	**Percentages (%)**
Between 1 and 10	4	4.65
Between 11 and 20	7	8.14
Between 21 and 30	2	2.33
Between 31 and 40	0	0.00
Between 41 and 50	3	3.49
More than 50	0	0.00
SUM	16	19.55%

Table 5: Research Evaluation Methods Used in Papers Results

Type of Evaluation	**Number**	**Percentage (%)**
Example application	45	52.33%
Experiment with human subjects	14	16.28%
Discussion	8	9.30%
Field experiment	6	6.98%
Simulation	6	6.98%
Case study	4	4.65%
Experiment with software subjects	2	2.33%
Experience	1	1.16%
SUM	86	100.01%

Again, only a couple of papers discussed browsing OWL without hiding the technical details [27, 42] and many more discussed browsing OWL but hiding the technical details [16, 78, 88, 56, 121, 29, 85]. In a similar vein of observation, [42, 59, 4] evaluated editing RDF data without hiding technical details while [53, 61, 10, 104, 100, 9, 57, 70, 118, 43, 59, 3, 4] did the same but hiding technical details. Furthermore, [24, 12, 42, 83, 4] discussed editing OWL data without hiding technical details and [49, 24, 10, 104, 121, 41, 78, 62, 4] discussed editing OWL data but hiding technical details.

Browsing and navigating—being an essential aspect of the UI on the web—was further broken down into a basic classification scheme. Nested-box (or faceted) layout was the most commonly explored browsing paradigm [70, 59, 81, 88, 56, 100, 61, 106, 85]. Table-like layout browsing was explored in [66, 3, 121] and node link or graph-based in [111, 27, 42, 14]. Finally, some form of hybrid browsing was evaluated in [54, 58], specialised widgets in [86] and other types of browsing that did not fit well into more common browsing paradigms were explored in [16, 40, 33].

3.3 Studies' Research Methodologies

A good majority of studies—81.39%, precisely—*did not* report on experiments involving human participants to evaluate the work: the remaining 18.61% did, and the distribution of how many participants were involved is shown in Table 4. Most papers had between 1 and 20 participants—an anticipated figure. The 17 papers that *did* conduct experiments involving human subjects were objects of a more rigorous quality assessment reported later in this paper subsection 3.4.

The results of the evaluation methods used in the reviewed papers are compiled and presented in Table 5. There is a majority of papers that used an "Example Application" with just over half of all reviewed papers. "Experiment with human subjects" was the second most preferred evaluation method with just under a fifth of all papers reviewed. The evaluation method will be correlated with other data in section 4.

Table 6: How Was Data Collected

Collection Method	Numbers	Percentages (%)
Did not collect data for this paper	57	66.28%
External Dataset (DBPedia, Existing database...)	11	12.79%
Interview	1	1.16%
Paper analysis	5	5.81%
Questionnaire/Survey	8	9.30%
Sample Dataset (Pseudo-random, Scenarios, etc.)	1	1.16%
Task-based	10	11.63%

Table 7: How was the Analysis Conducted

Analysis Method	Numbers	Percentages (%)
Descriptive analysis	15	17.44%
Did not collect data for this paper	58	66.44%
Descriptive statistics	5	5.81%
Statistical tests	8	9.30%
SUM	86	100.01%

We compiled some fine grained data on which methods are used for data collection in the selected 16 studies. More than one collection method was allowed for a single paper (see Table 6). The most popular means of collecting data were "Task-based" and "External Dataset" with 11.63% and 12.79% respectively. "Questionnaire/Survey" and "Paper Analysis (reading and simply taking casual notes)" were also used, but to a lesser extent with only roughly 15% combined. Note that the percentages are based on the total number of papers, and not only on the total of papers that *did* collect data.

The analysis employed for studies that collected data was recorded by classifying them in three broad categories: descriptive analysis for those providing qualitative insights from participants or other data sources, descriptive statistics for those providing only basic statistics (e.g. means, averages or frequencies), and statistical tests (e.g. Chi-squared test or t-test) (see Table 7).

3.4 Quality Assessment

The quality assessment was done in a similar fashion as in [15]; results are shown in Table 8. The overall average out of a possible 11 points was 6.71: a passing grade, but with much room for improvement.

All papers were research papers; this was expected since all papers included in this assessment were peer-reviewed papers collecting data from experiments with human subjects. Furthermore, all papers clearly defined the aim of their research. And, all but 2 papers established a good context in which to carry the research, with the only weak part being the elaborate discussion of skills and experience of participants and type of tools used.

Research design (i.e. Question 1 of Table 8) is where things start degrading for some papers: nearly half scored 0 on this aspect. Most researchers did not discuss how they decided which research methods to use to perform evaluations, nor did they provide alternative methods with justifications for their choices.

The recruitment strategy (i.e Question 5 of Table 8) was also a relatively weak area overall. The number of participants were usually statistically significant according to the mathematical model of the finding of usability problems presented in [89], but it is unclear if that model also applies to novel types of technologies such as the Semantic Web. It could be that novel UIs for the Semantic Web would require broader evaluations (e.g. preference over existing technologies) with carefully chosen research questions when designing the evaluation methods. It was rarely explained why the participants selected were the most appropriate to derive the sought out conclusions.

The use of control groups (i.e. Question 6 of Table 8) was practically absent for all but a couple of papers. The data collection process was surprisingly very weak considering the wealth of well established practises in all research fields—especially the closely related field of Human-Computer Interaction. It was not always clear how data was collected, the methods were not always explicit, and there was no quality control measures to assure accuracy and completeness of data collection.

The data analysis (i.e. Question 6 of Table 8) was even worse with less than a third of papers providing sufficiently rigorous analysis. There was almost never sufficient data to support the findings. In the rare cases where contradictory data was taken into account, only a brief discussion unsupported by the research evidence was provided. Approximately a third of the 16 papers did, however, provide a suitable statistical test to verify the results.

The relationship between researchers and participants was a very weak aspect as reflected by results of question 9 in Table 8: it indicates that there was no reported methods of how researchers controlled bias and their potential influence on each specific step of their studies. This is more understandable considering the constraints of this aspect of research (i.e. time, budget or availability of people). While it is not possible to apply the well established evidence-based medicine *gold standard* to reduce results biasing, we can develop and adopt modified protocols more fit to evidence-based software engineering [76].

The findings (i.e. Question 10 in Table 8) were most of the time explicit and clear: where most papers fell short was with providing adequate discussion of evidence, both for and against the researchers arguments; thoroughly discussing credibility of findings and study limitations; and properly justifying conclusions with results.

Results from question 9 in Table 8 indicates that most papers contributed some value to research and practice, discussed contributions to the field and identified new areas of research. However, not so many talked about how findings could be transferred to other populations or consider other ways in which the research could be used.

Table 8: Quality Assessment Detailed Score Card

Study	**1 Research**	**2 Aim**	**3 Context**	**4 R. Design**	**5 Sampling**	**6 Ctrl. Group**	**7 Data Coll.**	**8 Data Anal.**	**9 Bias**	**10 Findings**	**11 Value**	**Total**
S1[111]	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0	4.5
S2[55]	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	11.0
S3[52]	1.0	1.0	1.0	1.0	0.5	0.0	0.5	0.5	0.0	0.5	1.0	7.0
S4[4]	1.0	1.0	1.0	0.5	0.0	0.0	0.5	0.5	0.5	1.0	1.0	7.0
S5[13]	1.0	1.0	1.0	1.0	0.0	0.0	0.5	0.0	0.0	0.5	1.0	6.0
S6[62]	1.0	1.0	1.0	0.5	0.0	0.0	0.5	0.0	0.0	1.0	0.5	5.5
S7[54]	1.0	1.0	1.0	0.5	0.5	0.5	0.5	0.0	0.0	0.5	1.0	6.5
S8[84]	1.0	1.0	1.0	1.0	0.5	0.0	1.0	0.0	1.0	0.5	1.0	8.0
S9[57]	1.0	1.0	1.0	0.5	0.0	0.0	0.5	0.0	0.5	0.5	1.0	6.0
S10[40]	1.0	1.0	1.0	1.0	1.0	1.0	0.0	0.5	1.0	1.0	1.0	9.5
S11[5]	1.0	1.0	1.0	0.5	0.5	0.0	0.5	0.5	0.0	1.0	1.0	7.0
S12[121]	1.0	1.0	0.5	0.0	0.0	0.0	0.5	0.0	0.0	0.5	0.0	3.5
S13[14]	1.0	1.0	1.0	0.0	0.5	0.0	0.0	0.5	0.0	0.0	0.5	4.5
S14[60]	1.0	1.0	1.0	0.0	0.5	0.0	0.5	0.0	0.0	0.5	1.0	5.5
S15[71]	1.0	1.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	1.0	10.0
S16[24]	1.0	1.0	1.0	0.0	0.5	0.0	0.0	0.0	0.5	1.0	1.0	6.0
AVG	1.0	1.0	0.97	0.53	0.41	0.15	0.47	0.29	0.35	0.69	0.88	6.71

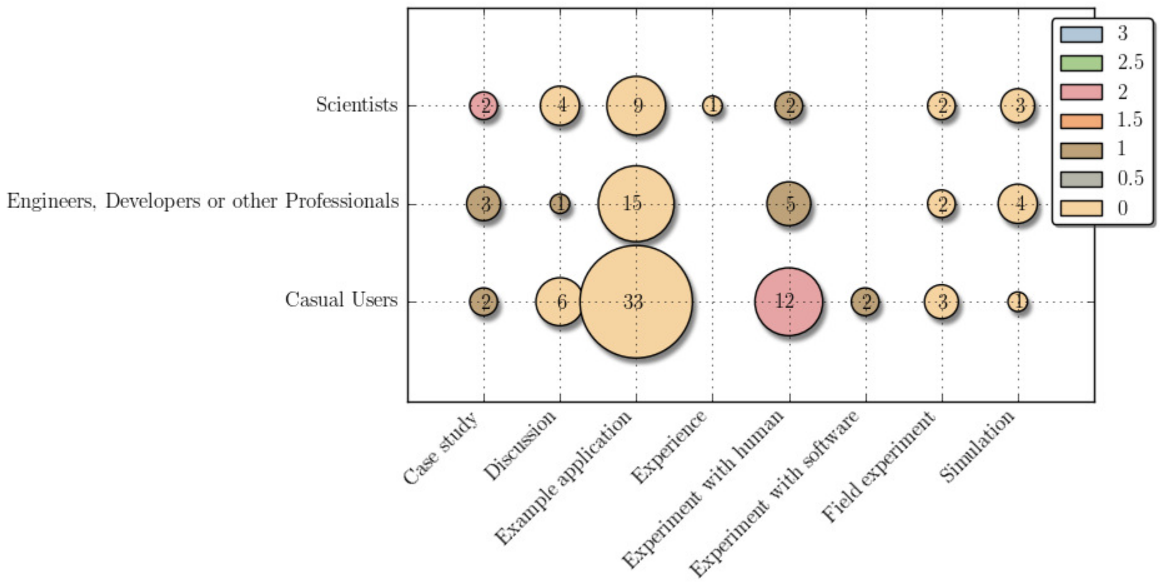

Figure 3: Target Users vs. Evaluation Methods

3.5 Target Users

We were interested in finding out what was the target audience of the Semantic Web UI. All papers reviewed discussed in one aspect or another Semantic Web UIs; but, the UI varied from highly specialised UI for ontology development targeted at knowledge engineers and researchers to basic browsing UI targeted at the casual users. The answer to this question for a given paper was not restricted to one choice only: a given UI for the Semantic Web could potentially target more than one group of users (e.g. advanced and normal users). As anticipated, most papers targeted casual users followed by engineers and finally scientists as shown in Table 9. This is hardly surprising when knowing that there are many more casual users then engineers and scientists: the relative proximity of the results for all three groups—that is, the empirical evidence that there is still relatively much UI work for scientists and engineers compared to their proportions in society—can be explained by the axiom that the Semantic Web is very much still a niche in the scientific community.

Table 9: Target Audience of Paper/Resource

Target Audience	**Numbers**	**Percentages (%)**
Casual Users	58	67.44%
Engineers, Developers or other Professionals	30	34.88%
Scientists	23	26.74%

More interesting information can be extracted by correlating the target users with research methodologies (Figure 3). Arguably, it can be deduced that most of the studies targeting scientists and engineers were mainly done in-house. This means that there was likely no proper distance between the researchers and study participants (e.g. colleagues take part in the study). Moreover, such studies usually did not involve a detailed research design, which would include carefully developed instruments (e.g. questionnaires) based on well accepted theories/models such as technology acceptance model [21, 116, 117] and task technology fit theory [47]. and organisation of experiments (e.g. controlled groups).

4 Discussion

All facets studied (e.g. subjects of papers, software engineering aspects and browsing, querying and searching) have been cross tabulated and carefully examined; the most interesting correlations are included and discussed here along with implications of findings.

Bubble charts are used to cross tabulate facets as in the exemplary mapping studies in [97, 67]. The x and y axes are used to collate all possible combinations of studied facets. Only the most interesting ones have been kept for discussions. However, unlike previous mapping studies, we added a third dimension to our bubble charts: a legend with a colour scale that provides the level of rigour of a particular bubble (i.e. cross tabulated area).

The level of rigour was assigned a value between 0 and 3 with constant increments of 0.5—0 being the least rigorous. The value was a rounded computed average [3] of all papers in a given bubble. It was decided to keep it simple, therefore, the averages were computed based on the responses to the question "If the paper collected data, how was the analysis done?" from our questionnaire (Appendix A). The choices to this question were assigned a value: Statistical tests–3 points; Descriptive statistics–2 points; Descriptive analysis–1 point, Did not collect data for this paper–0 point. This concept can probably be improved in a number of ways; we introduce it in the hope that it will be adopted and improved in future mapping studies.

4.1 Subject of Papers Facet

We wanted to know what type of research, in a broad sense, had been conducted and how: the mapping chart in Figure 4 shows "Subjects of papers" correlated with "Research Methodology". It is important to note that the *subject* of papers was defined in accordance to their primary focus. For example, only two papers were classified in "Browse, search or faceted interface", but many more discussed browsing and searching as is readily apparent from the results and coming discussions.

Approximately half the papers surveyed used "Example Application" as a research methodology, of which the vast majority were UI novel tools, frameworks, methodologies [29, 7, 45, 123, 33, 87, 103, 94, 42, 48, 96, 99, 102, 108, 23, 90, 6, 78, 16, 70, 118, 80, 43, 59] or user applications [82, 49, 110, 10, 104, 34, 91, 9, 92, 66]. Papers that were found to be more rigorous in their approaches were classified in "Experiment with human subject" [24, 71, 61, 14, 121, 5, 40, 52, 84, 54, 55, 13, 111, 4]; this comes as no surprise considering one of the factors we used in defining the rigour of papers (i.e. the rigour shown in the third dimension of the bubble charts) was whether or not human subjects were used in the evaluation method. However, as shown in Figure 4, it is obvious that the large majority of work has not been evaluated with the only method acceptable for research on UI—experiments with humans. Unfortunately, the dominant approach is to develop an application and provide an example of how that application can be used without any rigorous experiments with human subjects.

There is one gap of critical importance to the field under study: the lack of systematic reviews Figure 4. Of all papers that came out of a search with our keyword phrases as defined in subsection 2.2, only three were reviews—none were systematic maps and surveys. The importance of systematic maps and reviews should never be underestimated: they are critical in focusing new research in the right direction, identifying gaps, strengths and weaknesses [76, 113]. This paper is an effort in that direction: we aimed to bring the concept of systematic maps and reviews to the Semantic Web community.

In addition, we also wanted to investigate to what extend different subjects were actually supported by prototypes. Figure 5 correlates the paper subjects with the categories of prototypes developed, as reported in the studied papers. In this particular case, most of the gaps shown are expected and normal. For instance, one would not expect any ontology tool paper to present a communication, information systems or learning application prototype, nor you would not expect any of the UI reviews and surveys to present any prototypes—the same can be said for several cross correlations. However, it does show some important gaps; we list the most important ones below:

[3]Each average was rounded to the closest of the 7 possible values: 0, 0.5, 1, 1.5, 2, 2.5, 3

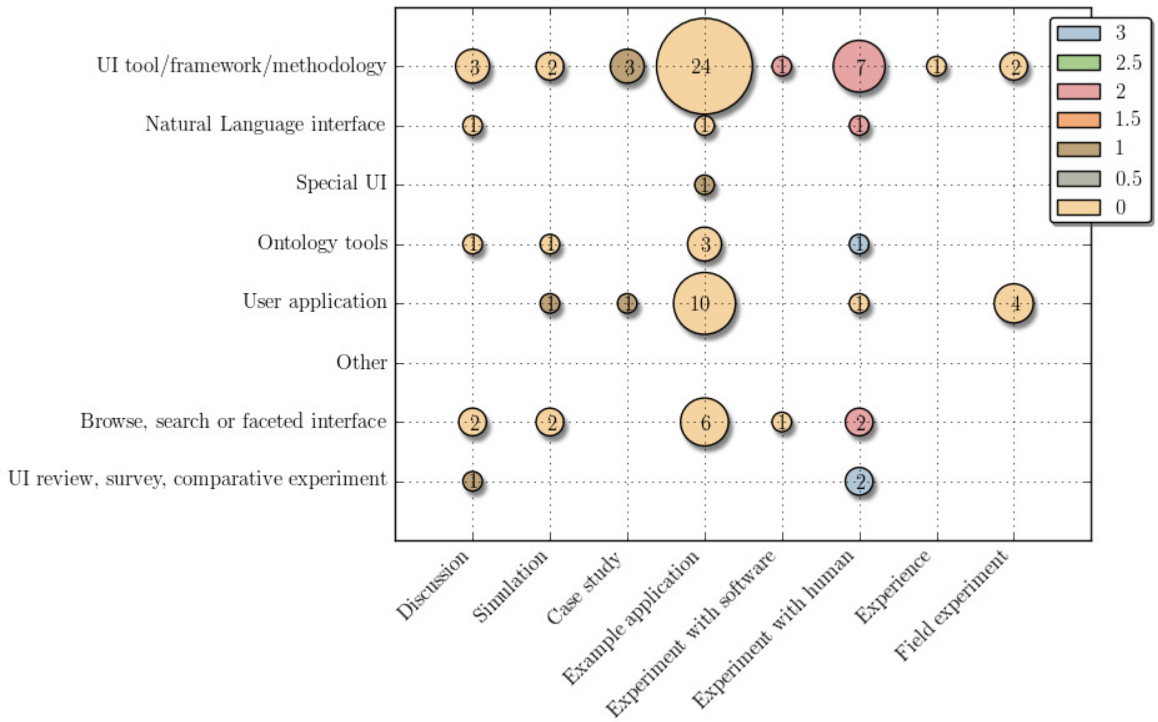

Figure 4: Paper Subjects vs. Evaluation Method

- Communication applications (e-mail, instant messaging, VoIP and on-line meeting platforms) are pretty much left out. Whether this is necessarily a gap the community needs to heed is a different question. Not all types of applications should be using the same data structures. A standardised graph data structure makes a lot of sense for many applications on the web for many reasons, but it certainly is not the holy grail of storing data on the Internet—this raises some important questions. Most would agree publishing linked data on the web has many benefits, but what data exactly should be published as such? For instance, for an on-line platform, what data would be published as open and externally query-able and why? What benefit would this bring, and who would benefit from it? But more inline with the focus of this paper, what types of UI would interface linked data in the context of communication applications? Would traditional UIs be best? Or would communication applications with a Semantic Technologies backend bring about whole new human computer interaction paradigms superseding long time and well known traditional ones?

- Learning applications are certainly the type of applications that could benefit from being built on a linked-data-like platform, yet there is little to no work done with regards to the UIs and user interaction paradigms in that area. The possibilities of building learning applications with Semantic Web technologies and publishing learning resources as linked data are tremendous [65, 25]: providing just in time learning, personalised learning, context and location aware learning, systematic collaborative learning and much more would be within reach. Ease-of-use and ease-of-learning of UIs in learning environments can improve students' application-specific computer self-efficacy, which is significantly related to learning performance [64].

- Search applications is another area where Semantic Web technologies could excel. Most modern search engines do not understand what you really want—they simply provide you with relatively good answers based on keywords indexing and some predefined algorithms. If data were published using Semantic

Web technologies it would be possible to build much smarter search engines. A smart engine is, however, only one component of the whole story. The success of present keyword search interfaces is mainly due to its simplicity for users. Experience would seem to suggest that a natural language interface would be the right choice for the next generation smart search engines—and indeed, some work is in progress in that area [72, 4, 68]. Nevertheless, there are certainly other interesting searching paradigms waiting to be discovered and evaluated: smarter faceted searching/browsing, contextualised and NLI hybrid, faceted and NLI hybrid just to list a few ideas.

- Natural language interfaces are typically evaluated on their own, and not much as been done to integrate them with browsing, communication, collaboration and various other types of commonly used applications; the same can be said of browsing and searching interfaces. We believe that most Semantic Web prototype applications should integrate some form of natural language searching capability—it would go a long way in demonstrating the power of linked data without alienating users with advanced concepts only computer savvy people can grasp.

- Special UI prototypes, in the context of this paper, mainly includes UIs with support for accessibility (i.e. suitable for people with special needs). Unfortunately, due to practicalities, accessibility in UIs is often a feature that comes after and often completely overlooked. Interestingly enough, breakthroughs in "Assistive Technology" using Semantic Web technologies could potentially, not only serve its intended purpose of enabling use of information technology for people with disability or impairment, but also demonstrate the power of linked data in other unintended ways. For example, developing information retrieval systems catering for people with visual impairment might also be useful in other contexts such as providing on demand information to people not in front of a computer display (e.g. brain computer interfaces, other ergonomic or organic UIs).

4.2 Software Engineering Facet

The gap between research and practice with regards to the Semantic Web is arguably quite large in comparison to other fields. Until recently with Google's announcement of what it calls the "Knowledge Graph", the Semantic Web was still a very small niche in the scientific community. Google presents the "Knowledge Graph" as a novel thing, but it really is just an implementation of what the researchers in the Semantic Web community have been working on for many years. Google offers little information as to the sources of its "Knowledge Graph", the type of linked-data or the schemas used [126]—it is nonetheless a huge step in the direction of the Semantic Web. We were interested in shedding some light on why it takes so long for research efforts to reach the practical world from a technical perspective. Data from the "Software Engineering" facet was correlated with a number of other facets (e.g. Figure 6, Figure 7 and Figure 8).

Some results were already known from other previous observations. For example, the "Example Application" classification contains the most papers; the "Experiment with humans" classification contains more rigorous papers Figure 6—this observation will reappear in several subsequent charts. However, several new noteworthy facts were revealed Figure 7:

- most of the rigorous papers where classified within "Node-based/graph-based layout browsing" [42, 14, 111, 27];

- there is a lack of papers discussing the frameworks for browsing paradigms;

- there is a lack of papers discussing automatically generating UIs; and,

- the most studied approach is the faceted browsing paradigm [85, 106, 61, 100, 56, 70, 81, 88, 59].

There are no reviews or surveys discussing any engineering aspects of Semantic Web UI Figure 8. In addition, other poorly studied areas with regards to software engineering aspects are natural language interfaces, ontology tools and special UIs which mainly discussed design [85, 114, 72, 83, 4] and architecture

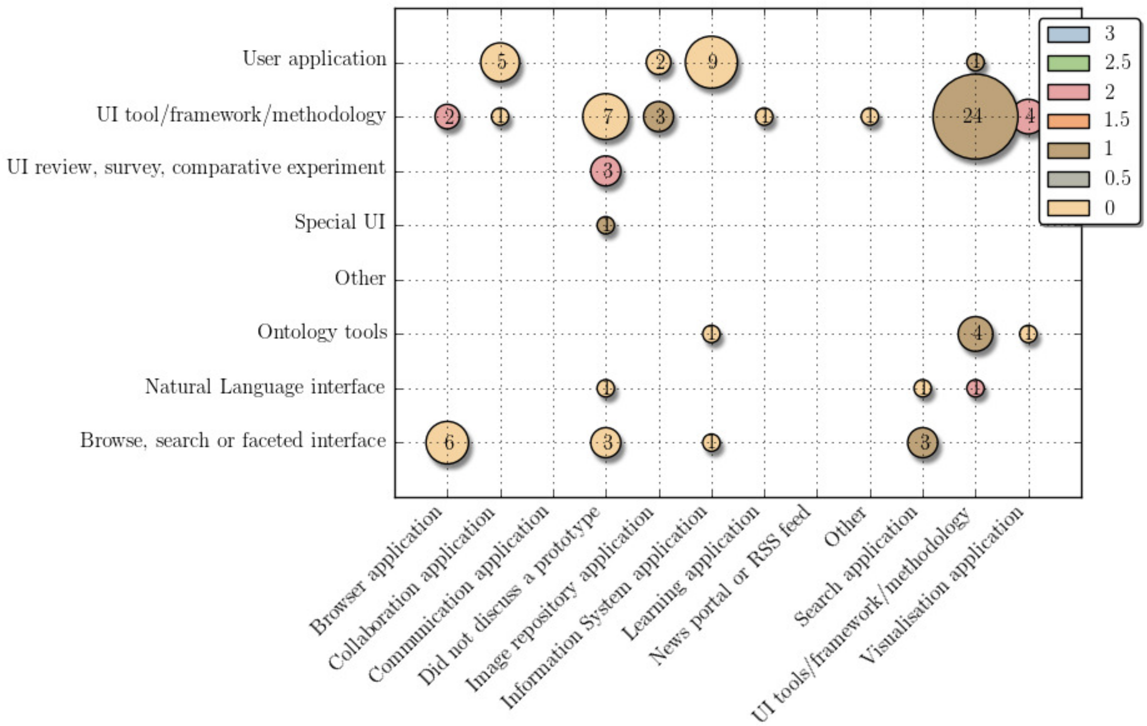

Figure 5: Paper Subjects vs. Prototypes

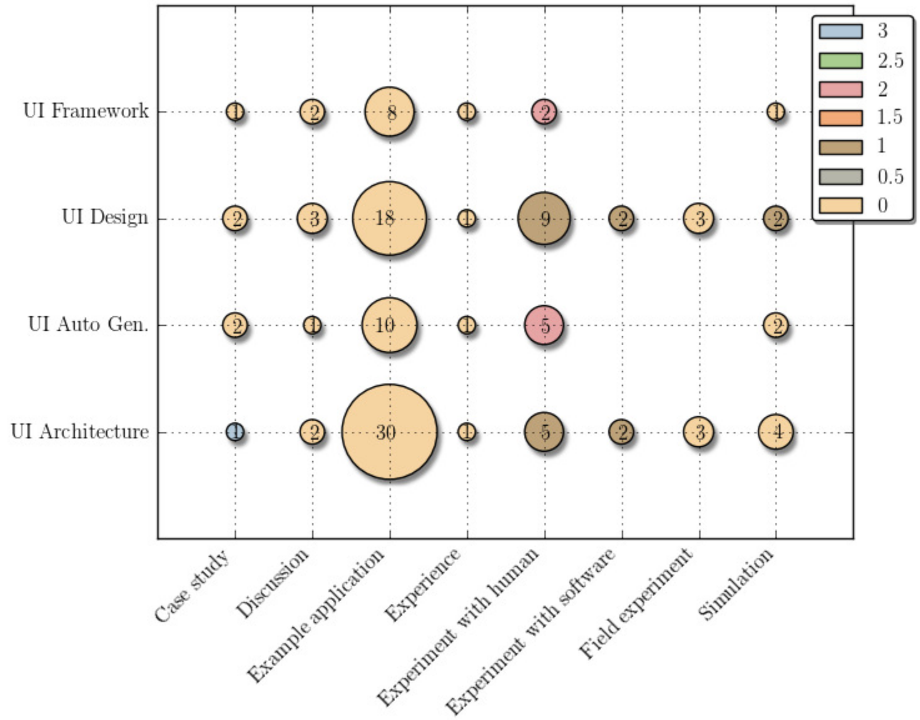

Figure 6: Software Engineering vs. Evaluation Method

[114, 38, 83, 4]. It is an impression that this is an area that could greatly benefit from more fined grained systematic maps and reviews. As stated previously, the gap between the research and the practical world is relatively large. The importance for good guidance with regards to software engineering UIs for the Semantic Web is critical; we think improving the state of research in this area would help in attracting software developers from both the open source community and the enterprise market.

The coverage of the broad software engineering aspects was generally good as shown in Figure 8. Most papers discussed some aspect of software engineering although not many did so in any amount of details for more than one aspect. For example, some had extensive presentation of an architecture of their proposed solution, but they fell short on a thorough discussion on the design aspect. The literature on software engineering aspects feels scattered with little integration at any level. Most of the time, it is hard to conceptualise the big picture—how all the components fit together and how they individually work. We would recommend that researchers working on Semantic Web UIs work more closely with software engineering researchers as this is an area that could improve.

A major gap that came out of Figure 7 was the lack of papers demonstrating frameworks for various browsing paradigms. This is understandable considering that browsing—and more generally, user interaction—paradigms are still largely unexplored when it comes to working with systems built with linked data and semantic technologies. Frameworks are useful abstractions that usually come later when the problem space is well understood. Working out proof of concepts based on elaborate design decisions and then thoroughly testing those assumptions and proposed approaches is where most of the focus should rely.

As pointed out in the results of Figure 8, natural language interfaces papers did cover some aspects of software engineering—mainly architecture and design. This is certainly a good start, but since NLI have matured fairly well over the years and is the only area with decent reviews, it would be great to start to see more framework studies to help the proliferation of NLIs in other Semantic Web UI research areas. Having well understood frameworks in the area of NLI might trigger a wave of developers starting to write libraries

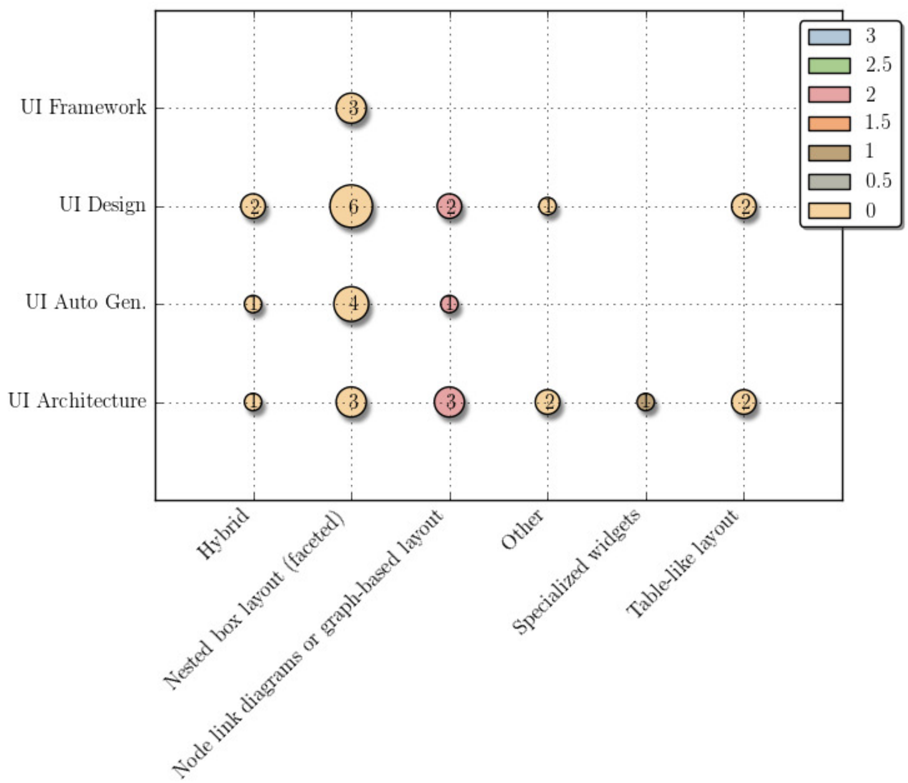

Figure 7: Software Engineering vs. Browsing Paradigms

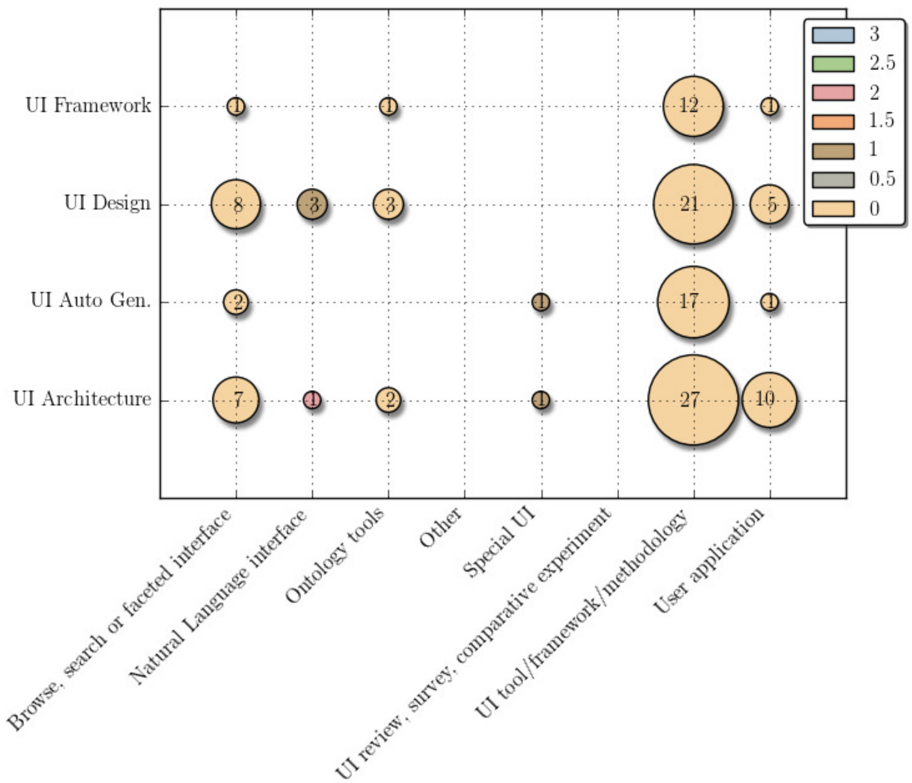

Figure 8: Software Engineering vs. Subject of Papers

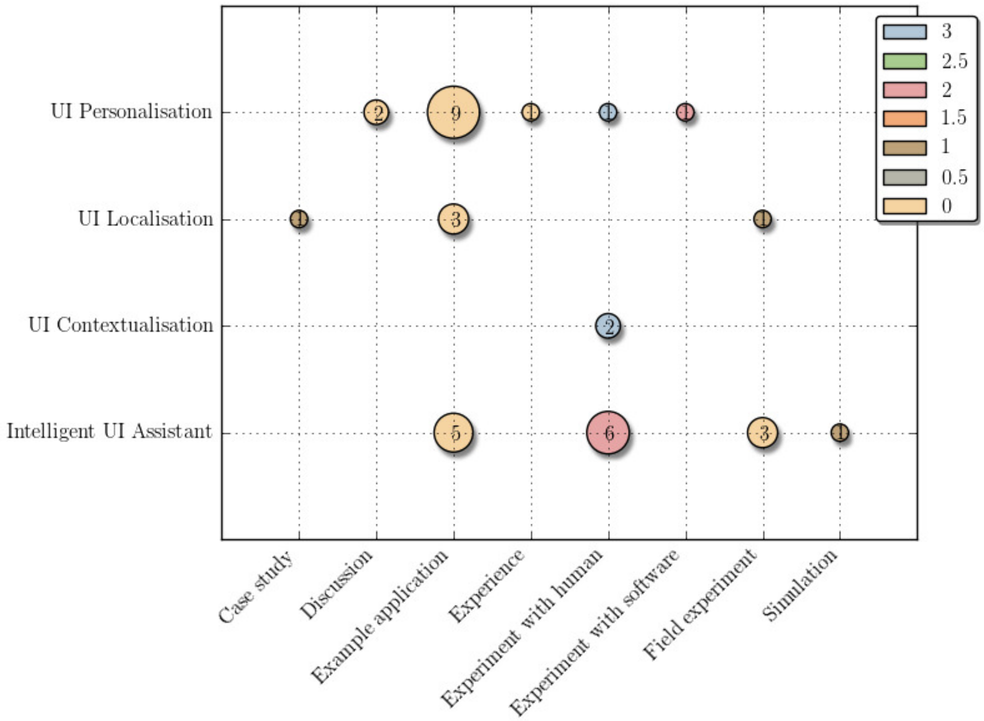

Figure 9: Intelligent UI vs. Evaluation Methods

in various programming languages to ease the integration of NLIs on linked data applications and platforms.

4.3 Intelligent UI

The study of intelligent user interfaces is an area that crosses several major research fields (interest research groups) such as Computer-Human Interaction, Software Engineering and Computer Science and is yet another area where the Semantic Web could potentially prove its high value. Unfortunately, little as been done in this area. Several cross tabulations are provided in Figure 9, Figure 10 and Figure 11 along with some discussions and analysis.

From Figure 9 we can observe that localisation and contextualisation of UIs on the Semantic Web are the two areas of intelligent UIs with the least attention. The lack of work with regards to localisation is expected; as with software frameworks, localisation typically is one of the last steps of implementation of most applications. Context-aware UIs, however, has a huge immediate research need. In order to leverage the full potential of Semantic Web UIs for developing context-aware applications, we need to consider different dimensions that context might include. To encourage further study of context aware UIs based on semantic technologies, we refer to the most widely accepted definition of context is the one given by [26]: "Context is any information that can be used to characterise the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves." Schmidt goes one step further to define 'the situation' as a relevant subset of the state of the world at a given point in time (including the respective knowledge of history and expectations for the future at that point in time) [105]. This clearly points out some fruitful venues of future research as such development of adaptive UIs based on distributed user models [11], which are built by integrating user information from different systems.

The nearly empty chart in Figure 10 indicates significant gaps with regards to intelligent browsing UIs. This could certainly be an interesting area for exploration. Browsing as remained more or less the same

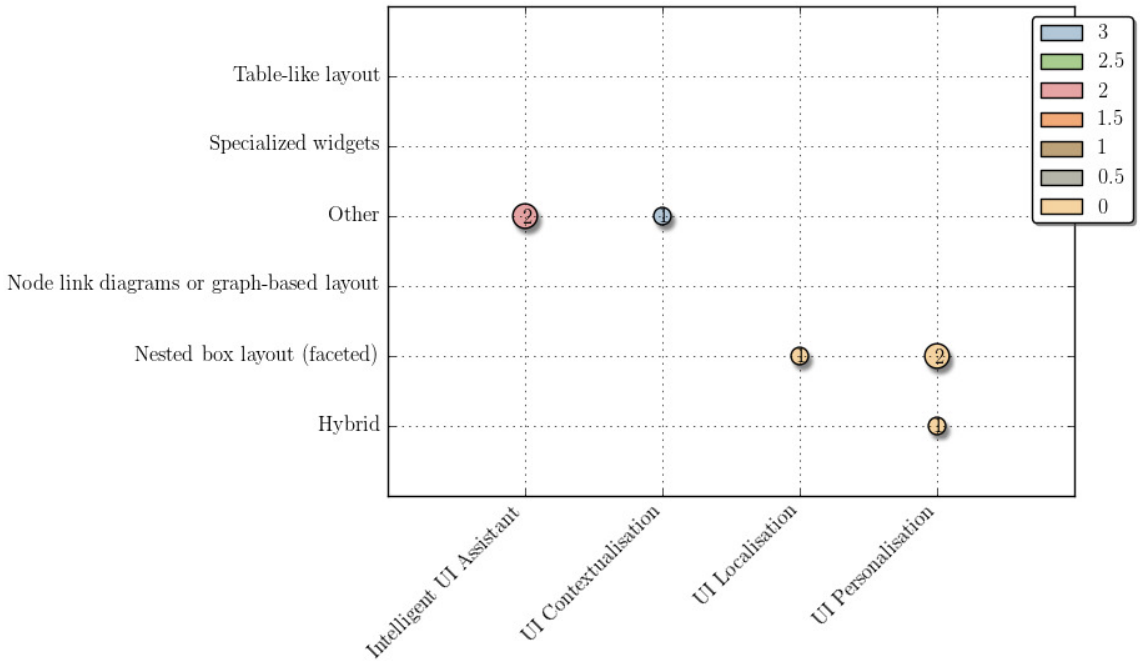

Figure 10: Intelligent UI vs. Browsing Paradigms

on the WWW since its birth: navigating through an ever growing collection of text documents through hyperlinks. Several papers have already started to introduce new browsing paradigms possible with Semantic Web technologies [85, 58, 106, 33, 61, 42, 14, 121, 100, 56, 40, 16, 54, 70, 66, 86, 81, 111, 88, 27, 59, 3] but only a handful of them integrated the notion of *personalisation* or some *intelligent assistant* and only one integrated the notion of *context*. All new browsing paradigms presented ways to browse information on the Semantic Web not so much browsing *intelligently*. This is certainly an area where interested researchers could innovate completely new ways of browsing.

Finally, Figure 11 shows gaps of prototypes with intelligent UIs, namely, “Communication application”, “Learning applications”, “News and other RSS Feed application”, and to a lesser extent “Collaboration applications” and “Visualisation applications”. All these applications could be made more appealing with intelligent browsing. For example, the ability for a student to browse the appropriate information within a given context during his learning would be a valuable feature in a learning application.

4.4 Practical Applications

The vast majority of papers (81.61% or 71 papers) presented a prototype of their proposed solution. However, several are discontinued [61, 128, 48, 14, 104, 114, 34, 31, 108, 9, 88], [112] [4] and many did not make their prototype available for scrutiny or for others to learn from [82, 29, 85, 7, 51, 12, 45, 33, 103, 77, 94, 42, 121, 99, 5, 40, 91, 22, 93, 90, 72, 6, 57, 50, 78, 84, 66, 55, 80, 81, 43, 122, 119, 4, 110]. Some have nicely

[4] http://www.smartweb-project.de/

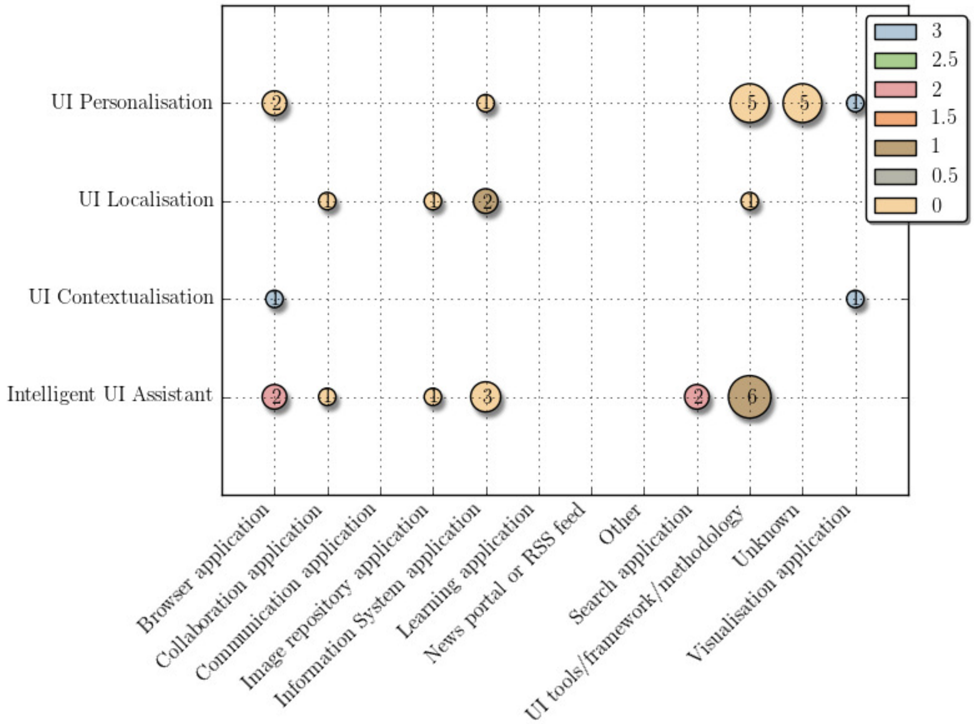

Figure 11: Intelligent UI vs. Prototypes

working prototypes [53] [5], [49] [6], [24] [7], [10] [8], [92] [9], [118] [10], [59] [11], [3] [12] but they are not as effective in demonstrating the potential of the Semantic Web—not because they do not provide services and features promised by the Semantic Web, but because they are applications that exist today (e.g wikis, social sites) which are not built using Semantic Web technologies (e.g. Wikipedia, Facebook). This does not mean they are not useful; they can easily do more than the same applications built using traditional approaches (e.g. FOAF vs. Facebook), but they do not necessarily attract attention. Very interesting prototypes demonstrating things that would be hard to achieve without the Semantic Web (or similar) technologies are available in [58] [13], [106] [14], [18] [15], [79] [16], [100] [17], [56] [18], [109] [19], [54] [20], [83] [21], [70] [22], [62] [23], [13] [24], [86]

[5] http://revyu.com/
[6] http://www.mindswap.org/2003/PhotoStuff/
[7] http://confluence.sourceforge.net/
[8] http://platypus.wikia.com/wiki/Platypus_Wiki
[9] http://semperwiki.wikispaces.com/
[10] http://sourceforge.net/projects/semediawiki
[11] http://simile-widgets.org/exhibit/
[12] http://www.w3.org/2005/ajar/tab
[13] http://simile.mit.edu/wiki/Piggy_Bank
[14] http://www.mspace.fm/
[15] https://code.google.com/p/aguia/
[16] http://autosparql.dl-learner.org/app/#home
[17] http://simile.mit.edu/hayloft/
[18] http://e-culture.multimedian.nl/software/ClioPatria.shtml
[19] http://www.aktors.org/technologies/ontoportal/
[20] http://www.visualdataweb.org/gfacet.php
[21] http://www.wsmostudio.org/semgov/paeditor2/org.semanticgov.ui_0.1.2.jar
[22] http://simile.mit.edu/hayloft/
[23] http://innovation.teilam.gr/ratsnake/
[24] http://www.service-finder.eu/

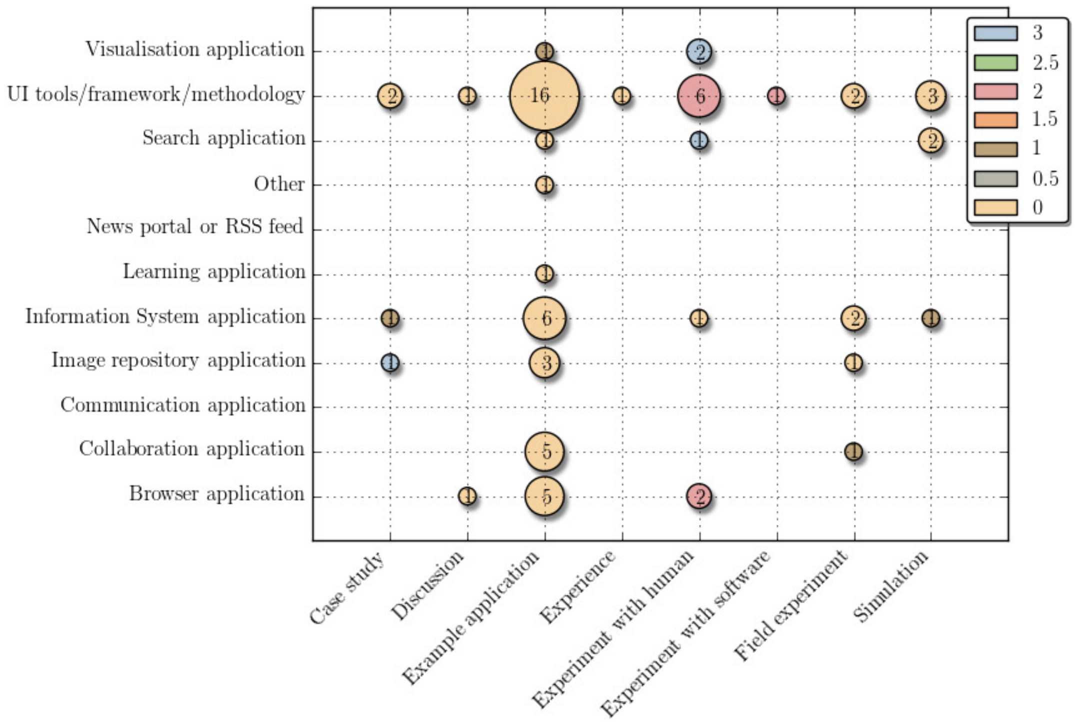

Figure 12: Prototype Categories vs. Research Methodology

[25] and [41] [26]. They offer excellent insight into what is possible to achieve with Semantic Web technologies.

Ideally, all prototypes should be made available for peers to scrutinise and/or learn from. Most projects that came out of the MIT lab [27] are excellent examples: the projects are all documented with source code available whether or not the project has become discontinued and/or irrelevant. Often, the community can learn just as much by scrutinising discontinued or abandoned research projects. There really is little to gain in keeping things secret when it comes to advancing science. We would recommend that all research prototypes would have a permanent home on sites such as GitHub [28] in order to provide long-term availability and service, thus, enabling easy contributions of communities with similar interests.

Types of "Prototypes" that have been developed correlated with "Research Methodology" is shown using a bubble chart mapping in Figure 12. The most popular prototypes presented where UI tools, information systems applications, collaborative applications and browser application. The prototypes discussed are categorised as follows: visualisation applications [42, 14, 55, 29, 85]; tools/frameworks/methodologies [24, 7, 51, 12, 18, 61, 94, 48, 41, 114, 91, 31, 108, 23, 93, 6, 109, 50, 78, 16, 84, 83, 70, 13, 80, 112, 43, 122, 59, 4]; search applications [72, 119, 5, 79]; learning application [99]; various kinds of information systems [81, 66, 88, 77, 57, 22, 34, 121, 110, 82, 86]; image repository applications [49, 90, 128, 62, 45]; collaborative applications (mainly wikis) [118, 53, 92, 9, 10, 104]; and browser application [54, 40, 56, 3, 100, 33, 106, 58].

Most papers did not collect any data at all to evaluate their proposed prototypes using established protocols. Prototypes tested with the most rigor included visualisation applications [14, 55], a search application [5] and an image repository application [62]. Unfortunately, of the four prototypes tested with more rigor, only the image repository application is available online—the others are either discontinued and/or not made available to peers.

[25] http://www.openflydata.org/
[26] http://semtalk.com/
[27] http://simile.mit.edu/
[28] http://github.com/

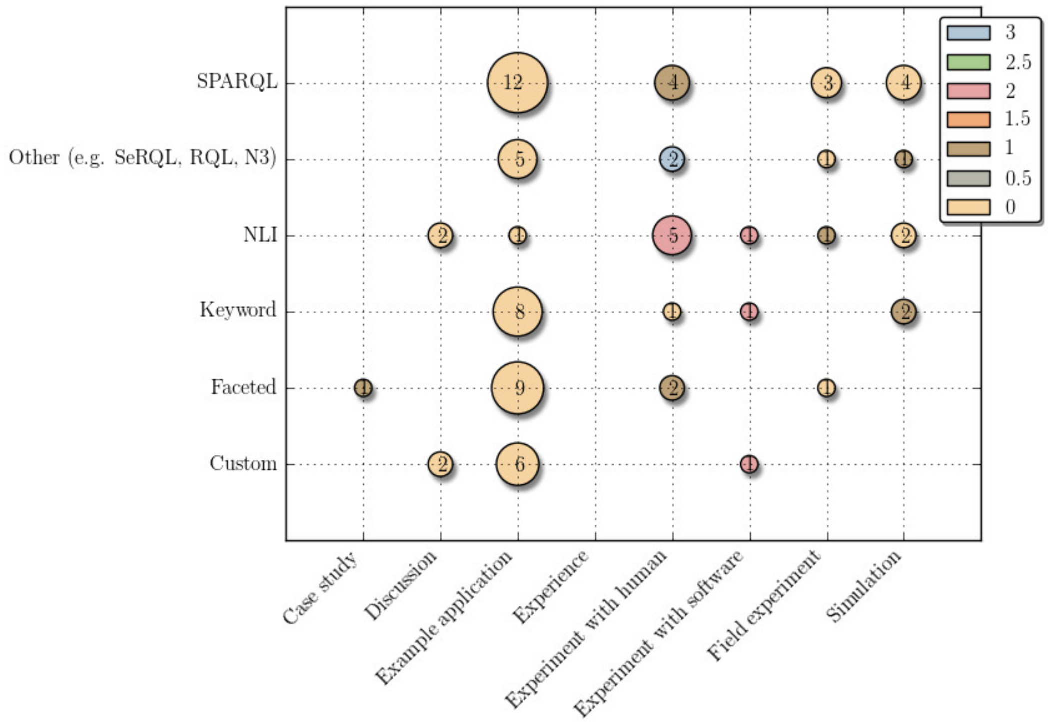

Figure 13: Querying vs. Evaluation Method

4.5 Querying and Search Interfaces

Querying and searching information is arguably one of the most useful and popular tasks people carry out on the Internet. Good querying and searching UIs for Semantic Web technologies are essential and could most certainly demonstrate their unprecedented capabilities. The research efforts were mapped by cross tabulating various facets and the most interesting are discussed herein.

Papers evaluating querying and searching interfaces were classified into broad categories and the overall research effort is mapped in Figure 13. Again, the level of rigor is quite poor—but that was expected. The Semantic Web, as a research community, has over a decade in the works. It stands to reason that querying and searching interfaces—arguably the most widely used UIs—should by now have a very solid foundation in the scientific literature. This is probably not the case yet. The intersection with the most rigour contains only two papers [5, 14] and are UIs for less commonly used querying languages now superseded by SPARQL (see Figure 13). Natural Language Interface UIs are doing better than most in terms of rigour, but, they too, could improve further. The most popular (and in many cases, recently developed) UIs "talk" the SPARQL querying language, yet little rigour in evaluating them exists. Existing (and future) novel SPARQL UIs should now employ evidence-based protocols [76] to thoroughly test their usability and effectiveness—we provide some guidance for doing this in subsection 3.4.

There seems to be a relatively widespread distribution of efforts intersecting prototype categories and various querying interfaces Figure 14. In other words, prototypes of various types were developed for most querying UIs; this is noteworthy and a plus for the Semantic Web community. The two most stricking exceptions are natural language querying and custom querying UIs which have not been prototyped in important areas such as communications, collaboration and learning applications. Custom querying has not been superseded by SPARQL like other less commonly used standard querying languages (e.g. RDQL), but it is certainly an area of exploration and does not have the same solid foundation—it is not expected to have prototypes of all types. However, NLI UIs are among the most mature and rigorously tested of all

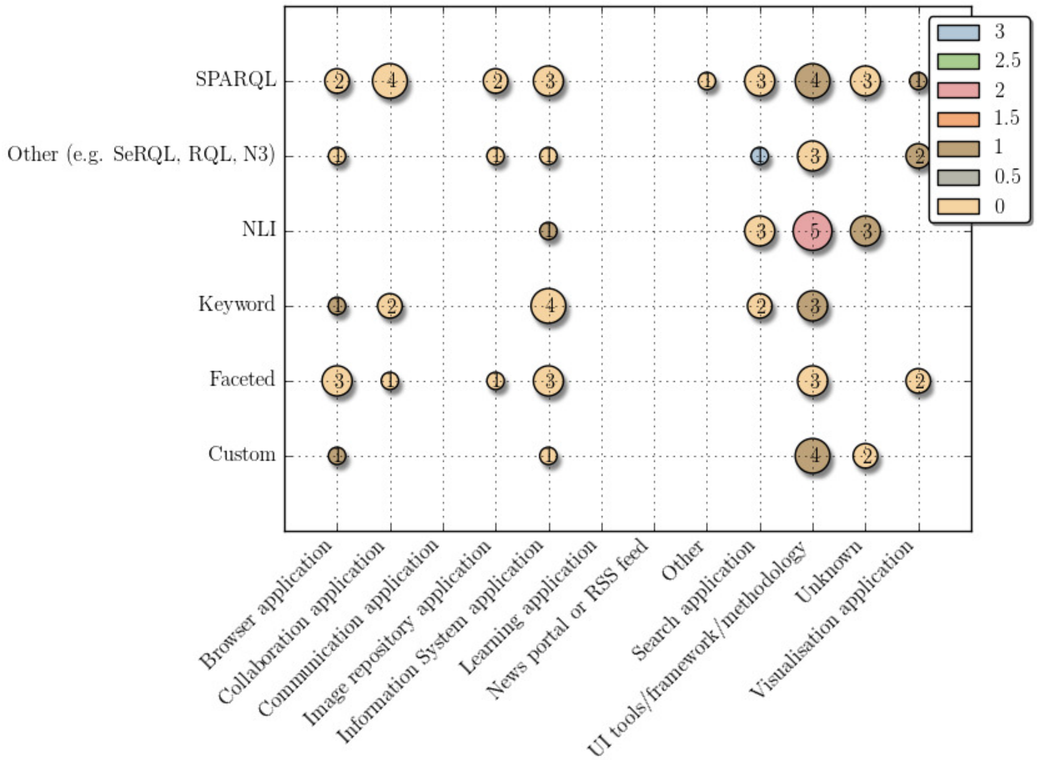

Figure 14: Querying vs. Prototypes

querying UIs to date. Not only are they excellent at showing the unprecedented capabilities of Semantic Web technologies, but they are often just as easy to use as keyword search UIs. There is a dire need of deveping prototypes of wikis, social networks and various communication applications with embedded NLI capabilities.

In general, evidence shows that there has been a relatively good coverage of the Semantic Web querying and searching UI sphere. The last mapping chart Figure 15 bears a mutual relation with Figure 14 in that they both display near widespread distribution of research coverage. However, there are two gaps that merit a small discussion: querying interfaces were not evaluated at all for special UIs, and there is only one literature review on querying interfaces (i.e. NLIs).

Although the importance of both reviews and special UIs have been stretched sufficiently in previous subsections, special UIs (typically UIs for people with special needs) can be discussed further still. It was mentioned in subsection 4.1 how work on special UIs could inadvertently result in breakthroughs that could even cater to a much wider audience due to a variety of reasons. In the context of querying and searching UIs the first thing that springs to mind is an intelligent personal *audio* assistant such as Siri in the iPhone 4S [29]. While Siri offers some appealing features, all it can do is a little more than scheduling meetings, sending emails or placing calls. On the fuzzy scale of artificial intelligence no doubt Siri would positioned itself on the low end. Obviously, data integration from diverse sources by using the linked data principles has a tremendous potential that can offer much superior personal assistants [19]. Audio, video, brain and physical touch interfaces to Semantic Web technologies have so much potential for future investigation—yet another compeling reason for the Semantic Web community to work more closely with the Human Computer Interaction community.

[29] http://www.apple.com/iphone/features/siri.html

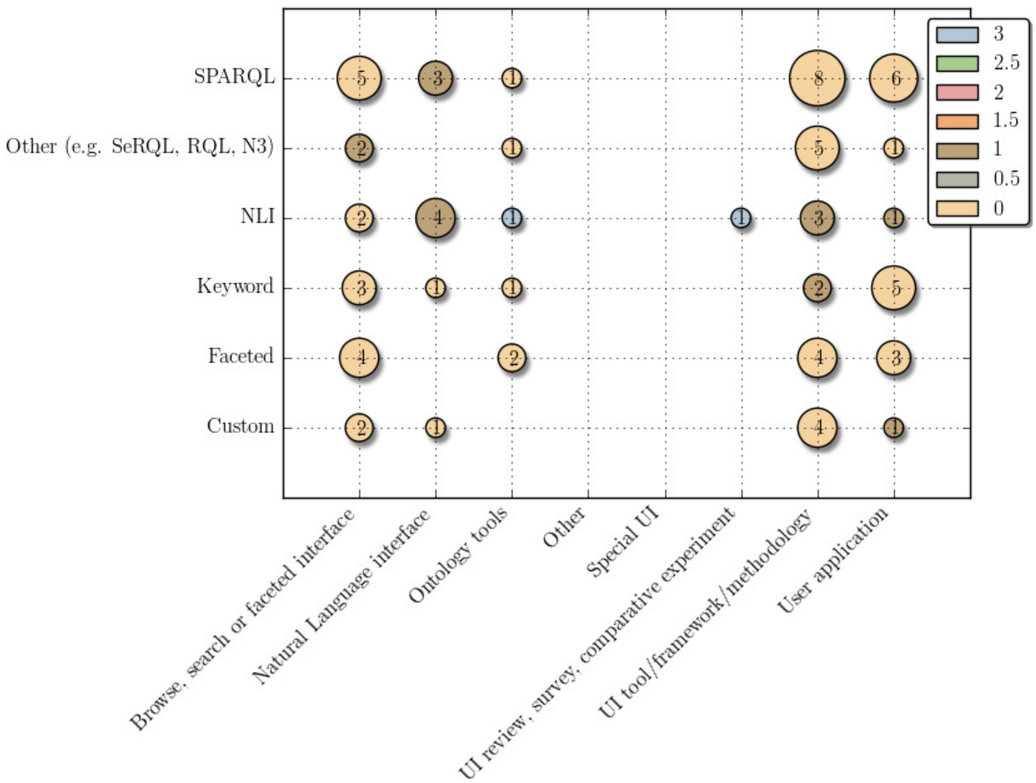

Figure 15: Querying vs. Subjects

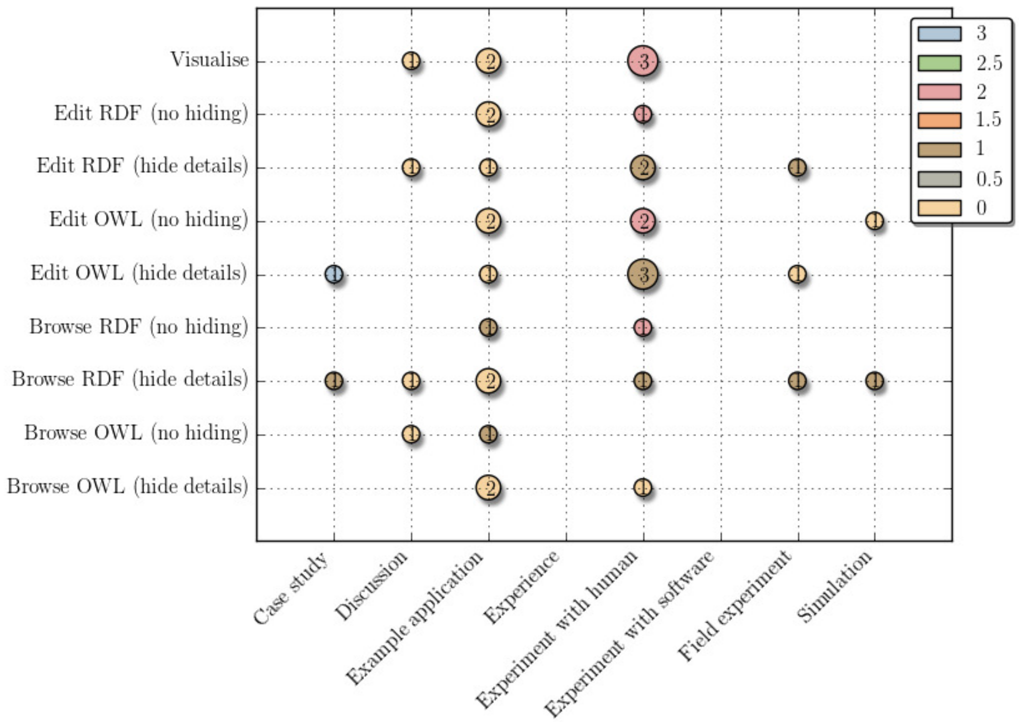

Figure 16: Visualisation, Browsing and Editing Facet vs Research Method

4.6 Visualisation, Browsing and Editing

A mapping of effort centred around the discussion of "Visualisation, browsing and editing" of semantic data and knowledge schemes vs. "Research Methodology" is depicted in Figure 16. The two most covered columns were "Example Application" and "Experiment with Humans", the latter were generally more rigorous. It is interesting to note, however, that there is a good distribution of efforts for all features of the "Visualisation, Editing and Browsing facet" (i.e. capabilities to visualise, edit RDF without hiding technical details, edit RDF hiding technical details...)—1 to 2 paper(s) discussed support for every feature.

The most studied browsing paradigm for Semantic Web UIs is faceted browsing while the most rigorously evaluated browsing paradigm is graph-based layout [111, 14] as shown in Figure 17.

The "Browsing paradigms" facet was correlated with "Prototypes" and the results are shown in Figure 18. Similar gaps can be observed here: collaboration, communication, learning and search applications have not really been evaluated in the context of browsing paradigms: in other words, studies evaluating browsing paradigms are still very much simply presenting a non domain specific browsing application [58, 106, 33, 100, 56, 40, 54, 3], a browsing tool or framework [61, 16, 70, 111, 59], or a visualisation application [42, 14, 85]. Some specific browsing paradigms were, however, evaluated in the context of information systems prototypes (e.g. table-like layout [66, 121], specialised widgets [86], and faceted [81, 88]). Hybrid approaches were not evaluated any prototypes excepts browsing applications [54, 58].

Browsing paradigms are correlated with querying methods in Figure 19. Clearly, faceted browsing is the only browsing paradigm that has been evaluated with most of the querying methods—albeit not with much rigour. Again, graph-based browsing supporting natural language interfaces type of querying [111] and other less common querying language standards [14] had more rigour in their evaluation approaches.

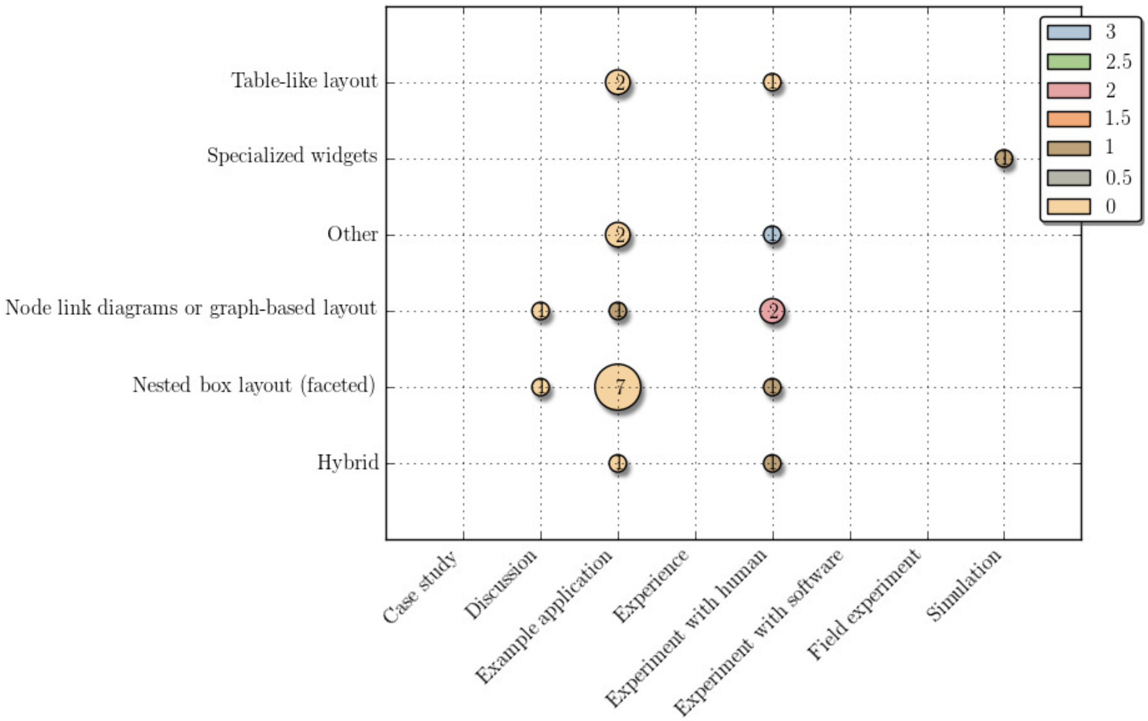

Figure 17: Browsing Paradigm vs Research Method

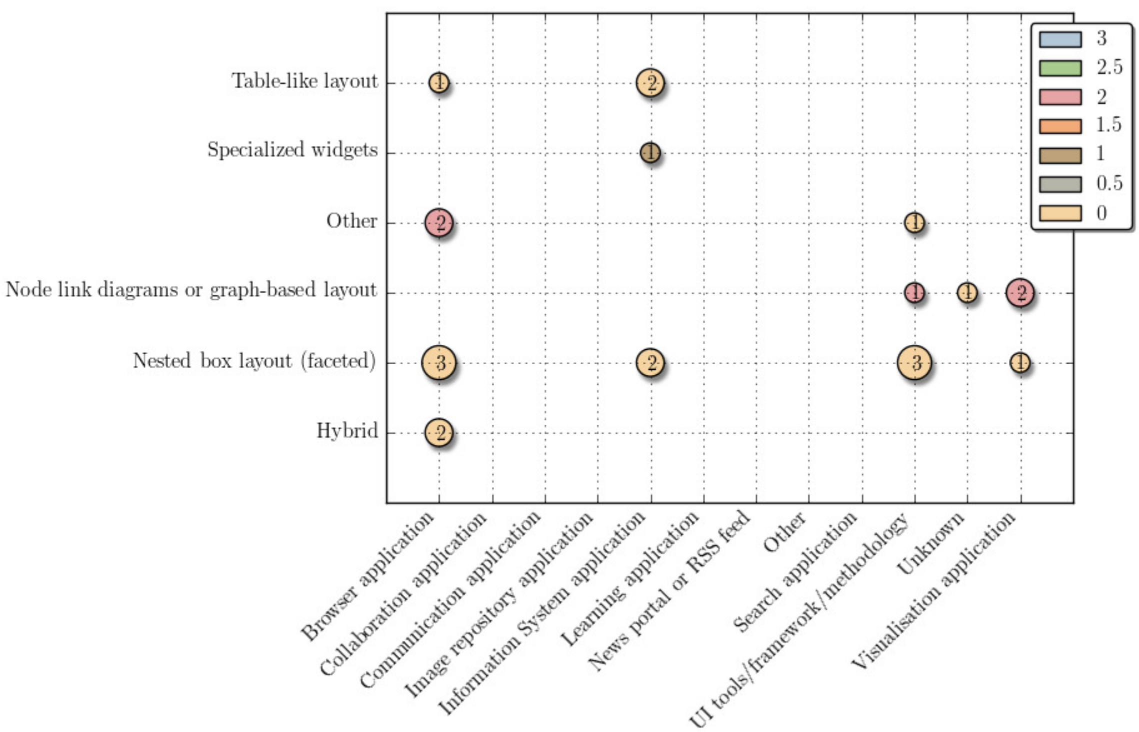

Figure 18: Browsing Paradigm vs. Prototypes

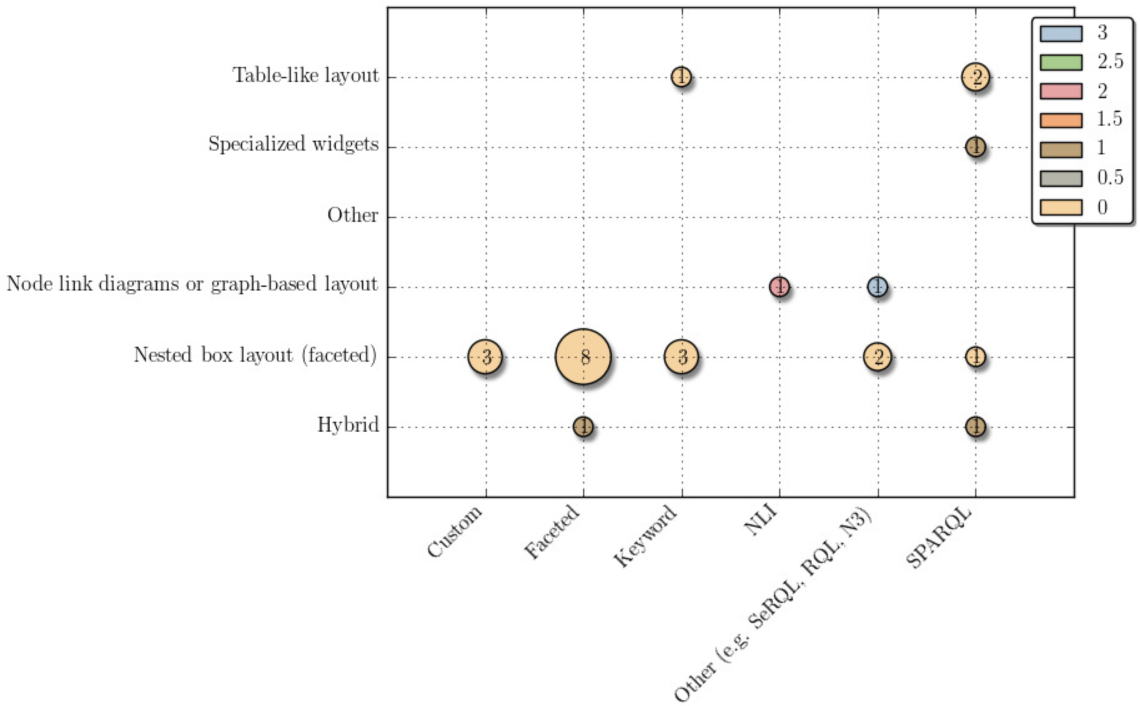

Figure 19: Browsing Paradigm vs. Querying

4.7 Limitations of this Review

This review has some limitations which need to be stated. The limitations are similar across other systematic reviews as well.

There is likely some important material that was not included in the review such as dissertations, related books or white papers and some relevant papers might not have been found in the digital databases using our search and selection protocol. While the former is a limitation of our review (and could be addressed in subsequent work) the latter is more a problem with how researchers write their abstracts and how digital databases classify and search published work. If abstracts were carefully written and included the keywords, there really is no reason why a keyword search would not return *all* published relevant content.

The classification of papers (e.g. by subjects or research methods) is a tricky aspect of systematic reviews; this is also noted by others [8, 69]. At times, there already exists classification schemes in the literature which can be ideally re-used or improved. However, this is not always the case, and to make matters worse, it is often not at all apparent what would be a good classification scheme. In addition, a well thought out classification scheme might not be the best fit for the existing published material. The approach taken in this review was to slowly *build* the classification scheme when going through the abstracts of all papers. One immediate problem with this approach is that it might fail to discover some gaps in the field. For example, there could be a missing category in a given classification scheme; had the category been included, one would clearly notice the relevant gaps. To reduce the threat of validity from this limitation, it is recommended that researchers very familiar with the field under review develop the classification schemes.

As mentioned earlier, only one author coded all papers. Therefore, some bias could have been introduced in the results for a variety of reasons such as the authors' subjectivity or different understanding of the questions from the coding book. Care was taken to avoid the latter by test piloting a sample of the reviewed papers and resolving any misunderstandings.

5 Conclusion

In this paper the Semantic Web UI literature was systematically reviewed and mapped. We defined a protocol in section 2 based on existing well accepted approaches for conducting literature reviews systematically [67, 97, 101, 17, 37, 74, 36, 35, 15, 75, 113]. The lack of reviews and the absence of existing systematic reviews and mapping studies of Semantic Web UIs shows the importance of this paper. Furthermore, an extensive discussion was provided identifying gaps and providing guidance for future research based on both the detailed results of section 3 and generated maps (i.e. bubble charts) in section 4.

It was found that there are gaps in several important areas which might hinder a wider adoption of Semantic Web technologies such as social network, mobile phone and e-learning applications. Furthermore, software engineering aspects of most papers need better work in order to bridge the gap between software developers and researchers. Intelligent UIs are probably the most promising direction to demonstrate the potential of Semantic Web technologies, yet little has been done in this area. On the bright side, querying, searching, visualising, browsing and editing interfaces have come a long way.

As stated in the introduction, many have started investigating Semantic Web UIs with the goal to improve broader acceptance of Semantic Web technologies. However, as shown in subsection 3.4, experimental research hardly used any proven theories and instruments specifically designed for investigating software technology acceptance. At best, some studies used instruments for validating usability [4] such as system usability scale (SUS) [2]. However, this scale, while suitable for comparing usability scores of alternative systems [30], it is not designed to evaluate potential acceptance of some software technology. Even more alarming is the fact that the majority of the studies published in the reviewed papers used weakly designed and not previously validated instruments.

For the Semantic Web research community to develop a solid body of research knowledge and establish empirically-validated principles, it is essential to build upon existing theories for examination of technology. Without such theoretical underpinnings, effectiveness of Semantic Web UIs cannot be accurately explained in terms of well-established constructs of behavioral influence. Thus, experience gained in developing and using one Semantic Web UI can hardly be generalized, while the research progress can be limited to a set of randomly conducted experiments. The Technology Acceptance Model (TAM), the best well-known theory of acceptance and use of information systems [21], is probably the most promising venue that researchers of Semantic Web UIs could use in their studies. In addition to its to two original main constructs (i.e. perceived ease-of-use and perceived usefulness), TAM has been extented with constructs of social influence and facilitating conditions [117, 116]. Validated through numerous (longitudinal) studies, TAM offers rigorous instruments (i.e., questionnaires) which can measure its four main constructs. The experimental evaluations of this model indicate that a potential technology acceptance is associated with the perceived usefulness, while the perceived usefulness is associated with perceived ease-of-use (only partially measured by SUS). Yet, in specific contexts of use, additional factors coming from social norms or constraints (e.g. costs) can additionally help determine if some software technology will be accepted or not in addition to perceived usefulness. In our study, we could not find any research published on Semantic Web UIs, which considered these two constructs of social influence and facilitating conditions. Of course, the use of TAM can also be complemented [30] with theories such as task-technology fit [47], which can assess whether a positive impact on individual and group performance is achieved through the fitness of a software technology for a particular task.

A Data Collection Instrument

A.1 Information not related to the Paper

- Who is the reviewer? [Ghislain Hachey, Dragan Gasevic]

[30] It is important to recall that hardly any empirical study used controlled experiments, and thus, could not fully exploit the SUS instrument

A.2 General Information for the Paper

- What is the type of publication? [Workshop, Conference, Journal, Other]
- What is the year of publication? [2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011]
- Does the paper report findings on human participants? [yes, no]
- If so, how many?
- If the paper collected data, how was it collected? [Questionnaire/Survey, Task-based, Interview, Paper analysis, Sample Data-set (Pseudo-random, Scenarios, etc.), External Data-set (DBPedia, Existing database...), Internal Data-set (System in use; their own data), Other, Did not collect data for this paper]
- What kind of paper was it? [Conference full research paper, Conference preliminary or work in progress, Conference tool demo, Conference workshop, Conference survey, Journal original research, Journal survey]
- What research evaluation method was used? [Case study, Discussion, Example application, Experience, Field experiment, Laboratory experiment with human subjects, Laboratory experiment with software subjects, Simulation]
- If the paper collected data, how was the analysis done? [Statistical tests (e.g. Chi-squared test nomogram, G-test, Likelihood-ratio tests, McNemar's test, Pearson's chi-square test, T-Test, Wald test or Other), Descriptive statistics (only basic statistics such as means, averages, frequencies, etc.), Descriptive analysis (i.e. Qualitative insights from participants), Did not collect data for this paper]
- Where in the world did the paper or resource originate from? [Africa, Asia-Pacific, Europe, Middle East, North America, South or Central America]
- Is the proposed solution being used by other researchers as a basis for their own improved research?
- Is the paper or resource targeted at (check all that apply)? [MANY Normal users, Advanced or expert users, Developers and Engineers, Researchers]

A.3 Quality Assessment Information

This subsection should only target papers which made use of participants to evaluate a research approach.

- **Is this a research paper?** [yes, partial, no] *Consider:*
  - Is the paper based on research (or is it merely a "lessons learnt" report based on expert opinion?
- Is there a **clear statement of the aims** of the research? [yes, partial, no] *Consider:*
  - Is there a rationale for why the study was undertaken?
  - Does the study involve users to evaluate the effect of a Semantic Web tool/technology? (excluding studies that involve users only in the pre- activities of the technology evaluation, e.g. gold-standard definition, using already available data log, or keyword collection)
  - Does the study present empirical data?
  - Is there a clear statement of the study's primary outcome (i.e. time-to- market, cost, or product or process quality)?
- Is there an adequate **description of the context** in which the research was carried out? [yes, partial, no] *Consider whether the researcher has identified:*

  - The domain/industry sector in which products/tools are used (e.g. banking, telecommunications, consumer goods, travel, etc.)
  - The skills and experience of participants(e.g. with , a method, a tool, an application domain)
  - The type of technology/tools used

- Was the **research design** appropriate to address the aims of the research? [yes, partial, no] *Consider:*
  - Has the researcher justified the research design (e.g. have they discussed how they decided which methods to use)?
  - Has the researcher provided an overview of alternative methods, and reasons on why (s)he chose this one?
  - Has the researcher justified the selection of this method considering the aim of the research?

- Was the recruitment strategy (i.e. **sampling**) appropriate to the aims of the research? [yes, partial, no] *Consider:*
  - Has the researcher explained how the participants or cases were identified and selected?
  - Are the cases defined and described precisely?
  - Were the cases representative of a defined population?
  - Have the researchers explained why the participants or cases they selected were the most appropriate to provide access to the type of knowledge sought by the study?
  - Was the sample size sufficiently large?

- Was there a **control group** with which to compare treatments? [yes, partial, no] *Consider:*
  - How were the controls selected?
  - Were they representative of a defined population?
  - Was there anything special about the controls?
  - Was the no-response high? Could non-respondents be different in any way?

- Was the **data collected** in a way that addressed the research issue? [yes, partial, no] *Consider:*
  - Were all measures clearly defined (e.g. unit and counting rules)?
  - Is it clear how data was collected (e.g. semi-structured interviews, focus group etc.)?
  - Has the researcher justified the methods that were chosen?
  - Has the researcher made the methods explicit (e.g. is there an indication of how interviews were conducted, did they use an interview guide)?
  - If the methods were modified during the study, has the researcher explained how and why?
  - Whether the form of the data is clear (e.g. tape recording, video material, notes etc.)
  - Whether quality control methods were used to ensure completeness and accuracy of data collection

- Was the **data analysis** sufficiently rigorous? [yes, partial, no] *Consider:*
  - Was there an in-depth description of the analysis process?
  - If thematic analysis was used, is it clear how the categories/ themes were derived from the data?
  - Has sufficient data been presented to support the findings?
  - To what extent has contradictory data been taken into account?
  - Whether quality control methods were used to verify the results (e.g. Kappa, ICC, Cronbach, etc.)

- Was the relationship between researcher and participants been considered to an adequate degree (i.e. **bias**)? [yes, partial, no] *Consider:*
  - Did the researcher critically examine their own role, potential bias and influence during the formulation of research questions, sample recruitment, data collection, and analysis and selection of data for presentation?
  - How the researcher responded to events during the study and whether they considered the implications of any changes in the research design.
- Is there a clear statement of **findings**? [yes, partial, no] *Consider:*
  - Are the findings explicit (e.g. magnitude of effect)?
  - Has an adequate discussion of the evidence, both for and against the researchers arguments been demonstrated?
  - Has the researcher discussed the credibility of their findings (e.g. triangulation, respondent validation, more than one analyst)?
  - Are limitations of the study discussed explicitly?
  - Are the findings discussed in relation to the original research questions?
  - Are the conclusions justified by the results?
- Is the study of **value** for research or practice? [yes, partial, no] *Consider:*
  - Does the researcher discuss the contribution the study makes to existing knowledge or understanding (e.g. do they consider the findings in relation to current practice or relevant research-based literature)?
  - Does the research identify new areas in which research is necessary?
  - Does the researcher discuss whether or how the findings can be transferred to other populations, or consider other ways in which the research can be used?

A.4 Semantic Web and User Interfaces Specific Information

A.4.1 Subject of Paper

- What was the main subject of the paper or resource? [Ontology tools (visualise, browse, edit, build, etc. RDF, OWL, RDFS...), Browse, search or faceted interface for the semantic web, Natural Language interface to the semantic web, User application for the semantic web, User interface tool/framework/methodology for the semantic web, User interface review, survey, comparative experiment, Special user interface for the semantic web (accessibility, mobile, etc.), Other]

A.4.2 UI Design, Framework and Architecture

- Does the paper discuss a UI framework for semantic web applications? [yes, no]
- Does the paper discuss design methodologies for a semantic web UI? [yes, no]
- Does the paper discuss a UI architecture for semantic web applications? [yes, no]
- Does the paper discuss any means of automatically generating UI (Model-Driven Development, Automatic visual presentation of semantic data, etc.) Visualisation of data or ontologies does not count here ? [yes, no]

A.4.3 Intelligent User Interface Aspects

- Does the paper discuss intelligent user assistants or some sort of guided mechanism for a user interface? [yes, no]
- Does the paper discuss personalisation services in a semantic web UI? [yes, no]
- Does the paper discuss contextualisation services (i.e. situational and spatial) to the user in the user interface?
- Does the paper discuss internationalisation and localisation (i.e. I18n,L10n) services to the user in the user interface? [yes, no]

A.4.4 Practical Applications

- Does the paper discuss the prototype (or completed product) of a practical application? [yes, no]
- If so, where would you categorise it? [UI tools/framework/methodology, News portal or RSS feed, Image repository application, Learning application, Search application, Browser application, Visualisation application, Information System application (includes more advanced systems such as Decision-Support systems, Knowledge bases, etc.), Collaboration applications (includes web2.0 user driven apps such as Twitter, LinkedIn and Facebook), Communication applications (e-mail, Instant Messaging, VoIP and On-line meeting systems), Other]

A.4.5 Querying and Search Interfaces

- Does the user interface discuss querying semantic data? [yes, no]
- Does the user interface query the semantic data using SPARQL (excludes SPARQL custom extensions)? [yes, no]
- Does the user interface query the semantic data using less common querying languages (e.g. SeRQL, RQL, N3)? [yes, no]
- Does the user interface query the semantic data using a custom querying language or method (includes SPARQL custom extensions)? [yes, no]
- Does the user interface query the semantic data using a natural language interface (questions translate into formal queries)? [yes, no]
- Does the user interface query/search the semantic data using a keyword-based interface (excludes NLI interfaces)? [yes, no]
- Does the paper discuss querying using a faceted interface (aka. view-based interfaces and semantic filters) to semantic data? [yes, no]

A.4.6 Visualising, Browsing and Editing

Visualising

- Does the paper discuss methods to visualise the semantic web (e.g. virtual reality, graph visualisation, automatic semantic presentation)? [yes, no]
- If the paper discusses an ontology visualisation tool, what type of visualisation does it support? [Detailed visualisation of concepts and relationships, Zooming in and out to enable visualisation of ontologies at various level of abstraction, Differentiates between schema and instances, Visualise the information spaces of ontologies, Tree-based visualisation of ontologies, Graph-based visualisation of ontologies, 3D]

Browsing

- Does the paper or resource discuss browsing of semantic data (RDF) of knowledge (OWL)?
- If the paper discusses a browsing interface such as a semantic web browser, what was the dominant representation paradigm (includes visualising interfaces)? [Nested box layout (faceted), Table-like layout, Node link diagrams or graph-based layout, Hybrid, Specialised widget, Paper did not discuss a browsing interface for the Semantic Web]
- Does the paper or resource discuss how to browse RDF data without hiding the technical details? [yes, no]
- Does the paper or resource discuss how to browse RDF data but hiding the technical details? [yes, no]
- Does the paper or resource discuss how to browse ontologies without hiding the technical details of the knowledge representation languages? [yes, no]
- Does the paper or resource discuss how to browse ontologies but hiding the technical details of the knowledge representation languages? [yes, no]

Editing (includes adding/deleting)

- Does the paper or resource discuss editing (add/delete/update) either data (RDF) or knowledge (OWL)? [yes, no]
- Does the paper or resource discuss ways to directly add or edit semantic data (i.e. RDF) content without hiding technical details? [yes, no]
- Does the paper or resource discuss ways to add or edit semantic data (i.e. RDF) content hiding technical details? [yes, no]
- Does the paper or resource discuss ways to directly add or edit semantic knowledge (i.e. OWL or other) content without hiding technical details knowledge representation languages? [yes, no]
- Does the paper or resource discuss ways to add or edit semantic knowledge (i.e. OWL or other) content hiding technical details of knowledge representation languages? [yes, no]

References

[1] S3db sparql endpoint.

[2] A. Bangor, P. T. Kortum, and J. T. Miller. An Empirical Evaluation of the System Usability Scale. *International Journal of Human-computer Interaction*, 24:574–594, 2008.

[3] T. Berners-Lee, J. Hollenbach, K. Lu, J. Presbrey, E. Prud'ommeaux, and mc schraefel. Tabulator redux: Browsing and writing linked data. In *Linked Data on the Web (LDOW2008)*, 2008.

[4] A. Bernstein and E. Kaufmann. GINO - a guided input natural language ontology editor. In *The Semantic Web - ISWC 2006*, volume 4273 of *Lecture Notes in Computer Science*, pages 144–157. Springer Berlin / Heidelberg, 2006.

[5] A. Bernstein, E. Kaufmann, and C. Kaiser. Querying the semantic web with ginseng: A guided input natural language search engine. In *In: 15th Workshop on Information Technologies and Systems, Las Vegas, NV*, pages 112–126, 2005.

[6] J.-S. Brunner and P. Gatellier. Raise semantics at the user level for dynamic and interactive soa-based portals. In *Proceedings of the 18th international conference on World wide web*, WWW '09, pages 1137–1138, New York, NY, USA, 2009. ACM.

[7] M. Brunzel and R. M. Mueller. Handling of task hierarchies on the nepomuk social semantic desktop. In *Proceedings of the 10th international conference on Visual Information Systems: Web-Based Visual Information Search and Management*, VISUAL '08, pages 315–318, Berlin, Heidelberg, 2008. Springer-Verlag.

[8] D. Budgen, A. J. Burn, O. P. Brereton, B. A. Kitchenham, and R. Pretorius. Empirical evidence about the uml: a systematic literature review. *Software: Practice and Experience*, 41(4):363–392, 2011.

[9] M. Buffa, F. Gandon, G. Ereteo, P. Sander, and C. Faron. Sweetwiki: A semantic wiki. *Web Semantics: Science, Services and Agents on the World Wide Web*, 6(1):84–97, 2008.

[10] S. E. Campanini, P. Castagna, and R. Tazzoli. Platypus wiki: a semantic wiki wiki web. In *in Proceedings of the First Italian Semantic Web Workshop*, 2004.

[11] F. Carmagnola and V. Dimitrova. An evidence-based approach to handle semantic heterogeneity in interoperable distributed user models. In *AH*, pages 73–82, 2008.

[12] R. N. Carvalho, L. L. Santos, M. Ladeira, and P. C. G. Costa. A gui tool for plausible reasoning in the semantic web using mebn. In *Proceedings of the Seventh International Conference on Intelligent Systems Design and Applications*, pages 381–386, Washington, DC, USA, 2007. IEEE Computer Society.

[13] I. Celino and F. Corcoglioniti. Towards the formalization of interaction semantics. In *Proceedings of the 6th International Conference on Semantic Systems*, I-SEMANTICS '10, pages 10:1–10:8, New York, NY, USA, 2010. ACM.

[14] I.-X. Chen, C.-Z. Yang, and T.-L. Hsu. Design and evaluation of a panoramic visualization environment on semantic web. *Information and Software Technology*, 48(6):402–409, 2006.

[15] L. Chen and M. Ali Babar. A systematic review of evaluation of variability management approaches in software product lines. *Inf. Softw. Technol.*, April 2011.

[16] S. Chen, S. Nepal, and A. Bouguettaya. A smart user interface for service-oriented web. In D. Chiu, L. Bellatreche, H. Sasaki, H.-f. Leung, S.-C. Cheung, H. Hu, and J. Shao, editors, *Web Information Systems Engineering - WISE 2010 Workshops*, volume 6724 of *Lecture Notes in Computer Science*, pages 318–330. Springer Berlin / Heidelberg, 2011.

[17] H. M. Cooper. Organizing knowledge syntheses: A taxonomy of literature reviews. *Knowledge, Technology & Policy*, 1(1):104–126, March 1988.

[18] M. Correa, H. Deus, A. Vasconcelos, Y. Hayashi, J. Ajani, S. Patnana, and J. Almeida. Aguia: autonomous graphical user interface assembly for clinical trials semantic data services. *BMC Medical Informatics and Decision Making*, 10:1–13, 2010.

[19] R. S. Cost, T. W. Finin, A. Joshi, Y. Peng, C. K. Nicholas, I. Soboroff, H. Chen, L. Kagal, F. Perich, Y. Zou, and S. Tolia. Ittalks: A case study in the semantic web and daml+oil. *IEEE Intelligent Systems*, 17(1):40–47, 2002.

[20] F. Q. B. da Silva, A. L. M. Santos, S. Soares, A. C. C. França, C. V. F. Monteiro, and F. F. Maciel. Six years of systematic literature reviews in software engineering: An updated tertiary study. *Inf. Softw. Technol.*, 53(9):899–913, Sept. 2011.

[21] F. D. Davis. Perceived usefulness, perceived ease of use, and user acceptance of information technology (misq 89). *Management Information Systems Quarterly*, 13:319–339, 1989.

[22] C. De Maio, V. Loia, G. Fenza, M. Gallo, R. Linciano, and A. Morrone. Fuzzy knowledge approach to automatic disease diagnosis. In *Fuzzy Systems (FUZZ), 2011 IEEE International Conference on*, pages 2088–2095, june 2011.

[23] S. de Moura and D. Schwabe. Interface development for hypermedia applications in the semantic web. In *WebMedia and LA-Web, 2004. Proceedings*, pages 106 – 113, oct. 2004.

[24] R. Denaux, C. Dolbear, G. Hart, V. Dimitrova, and A. G. Cohn. Supporting domain experts to construct conceptual ontologies: A holistic approach. *Web Semantics: Science, Services and Agents on the World Wide Web*, 9(2):113–127, 2011.

[25] V. Devedšić. *Semantic Web and Education*. Springer, Berlin Heidelberg New York, 2006.

[26] A. K. Dey. Understanding and using context. *Personal Ubiquitous Comput.*, 5(1):4–7, Jan. 2001.

[27] A. Dhawan and A. Nolan. Poster: Designing reusable user-interfaces for browsing a collection of neuroscience ontologies. In *Computational Advances in Bio and Medical Sciences (ICCABS), 2011 IEEE 1st International Conference on*, page 240, feb. 2011.

[28] O. Dieste, A. Grimán, and N. Juristo. Developing search strategies for detecting relevant experiments. *Empirical Softw. Engg.*, 14(5):513–539, Oct. 2009.

[29] D. A. Dimitrov, R. Pundaleeka, A. Qasem, and J. Hein. Isens: A system for information integration, exploration, and querying of multi-ontology data sources. In *Proceedings of the 2009 IEEE International Conference on Semantic Computing*, ICSC '09, pages 330–335, Washington, DC, USA, 2009. IEEE Computer Society.

[30] M. T. Dishaw and D. M. Strong. Extending the technology acceptance model with task-technology fit constructs. *Information and Management*, 36:9–21, 1999.

[31] A. Dix, G. Lepouras, A. Katifori, C. Vassilakis, T. Catarci, A. Poggi, Y. Ioannidis, M. Mora, I. Daradimos, N. Md.Akim, S. R. Humayoun, and F. Terella. From the web of data to a world of action. *Web Semantics: Science, Services and Agents on the World Wide Web*, 8(4):394–408, 2010.

[32] M. Doller, R. Tous, M. Gruhne, K. Yoon, M. Sano, and I. S. Burnett. The mpeg query format: Unifying access to multimedia retrieval systems. *IEEE Multimedia*, 15:82–95, 2008.

[33] J. Domingue and M. Dzbor. Magpie: supporting browsing and navigation on the semantic web. In *IUI '04: Proceedings of the 9th international conference on Intelligent user interfaces*, pages 191–197, New York, NY, USA, 2004. ACM.

[34] J. Domingue, A. Stutt, M. Martins, J. Tan, H. Petursson, and E. Motta. Supporting online shopping through a combination of ontologies and interface metaphors. *International Journal of Human-Computer Studies*, 59(5):699–723, 2003.

[35] T. Dybå and T. Dingsøyr. Empirical studies of agile software development: A systematic review. *Inf. Softw. Technol.*, 50:833–859, August 2008.

[36] T. Dybå and T. Dingsøyr. Strength of evidence in systematic reviews in software engineering. In *Proceedings of the Second ACM-IEEE international symposium on Empirical software engineering and measurement*, ESEM '08, pages 178–187, New York, NY, USA, 2008. ACM.

[37] T. Dybå, T. Dingsøyr, and G. Hanssen. Applying systematic reviews to diverse study types: An experience report. In *Empirical Software Engineering and Measurement, 2007. ESEM 2007. First International Symposium on*, pages 225–234, sept. 2007.

[38] B. Encelle and N. Baptiste-Jessel. Generating adaptable user interfaces for browsing xml documents user interfaces adaptation using user profiles of applications policies. In *Autonomic and Autonomous Systems, 2007. ICAS07. Third International Conference on*, page 66, june 2007.

[39] E. Engström and P. Runeson. Software product line testing - a systematic mapping study. *Inf. Softw. Technol.*, 53(1):2–13, Jan. 2011.

[40] A. Faaborg and H. Lieberman. A goal-oriented web browser. In *CHI '06: Proceedings of the SIGCHI conference on Human Factors in computing systems*, pages 751–760, New York, NY, USA, 2006. ACM.

[41] C. Fillies, G. Wood-Albrecht, and F. Weichhardt. Pragmatic applications of the semantic web using semtalk. *Computer Networks*, 42(5):599–615, 2003.

[42] F. Frasincar, R. Telea, and G. jan Houben. Adapting graph visualization techniques for the visualization of rdf data. In *of RDF data, Visualizing the Semantic Web, 2006*, pages 154–171, 2005.

[43] M. Fuchs, C. Niederée, M. Hemmje, and E. J. Neuhold. Supporting model-based construction of semantic-enabled web applications. In *Proceedings of the Fourth International Conference on Web Information Systems Engineering*, WISE '03, pages 232–, Washington, DC, USA, 2003. IEEE Computer Society.

[44] F. Gandon. Generating surrogates to make the semantic web intelligible to end-users. In *Web Intelligence, 2005. Proceedings. The 2005 IEEE/WIC/ACM International Conference on*, pages 352 – 358, sept. 2005.

[45] X. Giro-i Nieto, C. Ventura, J. Pont-Tuset, S. Cortes, and F. Marques. System architecture of a web service for content-based image retrieval. In *Proceedings of the ACM International Conference on Image and Video Retrieval*, CIVR '10, pages 358–365, New York, NY, USA, 2010. ACM.

[46] R. L. Glass, I. Vessey, and V. Ramesh. Research in software engineering: an analysis of the literature. *Information and Software Technology*, 44(8):491–506, 2002.

[47] D. L. Goodhue. Understanding user evaluations of information systems. *Management Science 41(12)*, pages 1827–1844, 1995.

[48] M. Gruhn, S. Foll, J. Pontow, D. Linner, and I. Radusch. Semantic locations in online communities. In *Semantic Computing, 2007. ICSC 2007. International Conference on*, pages 224–234, sept. 2007.

[49] C. Halaschek-Wiener, J. Golbeck, A. Schain, M. Grove, B. Parsia, and J. Hendler. Photostuff - an image annotation tool for the semantic web. In *Proceedings of the 4th International Semantic Web Conference*, 2005.

[50] A. Haller and F. Rosenberg. A semantic web enabled form model and restful service implementation [replaces: Activeraul: A model-view-controller approach for semantic web applications]. In *Service-Oriented Computing and Applications (SOCA), 2010 IEEE International Conference on*, pages 1–8, dec. 2010.

[51] J. He, I.-L. Yen, T. Peng, J. Dong, and F. Bastani. An adaptive user interface generation framework for web services. In *Congress on Services Part II, 2008. SERVICES-2. IEEE*, pages 175–182, sept. 2008.

[52] T. Heath, J. Domingue, and P. Shabajee. User interaction and uptake challenges to successfully deploying semantic web technologies. In *in Proc. 3rd International Semantic Web User Interaction Workshop*, 2006.

[53] T. Heath and E. Motta. Ease of interaction plus ease of integration: Combining web2.0 and the semantic web in a reviewing site. *Web Semantics: Science, Services and Agents on the World Wide Web*, 6(1):76–83, 2008.

[54] P. Heim, J. Ziegler, and S. Lohmann. gfacet: A browser for the web of data.

[55] R. Hervás and J. Bravo. Towards the ubiquitous visualization: Adaptive user-interfaces based on the semantic web. *Interacting with Computers*, 23(1):40–56, 2011.

[56] M. Hildebrand, J. van Ossenbruggen, and L. Hardman. /facet a browser for heterogeneous semantic web repositories. In *The Semantic Web - ISWC 2006*, volume 4273 of *Lecture Notes in Computer Science*, pages 272–285. Springer Berlin / Heidelberg, 2006.

[57] M. Hildebrand, J. van Ossenbruggen, L. Hardman, and G. Jacobs. Supporting subject matter annotation using heterogeneous thesauri: A user study in web data reuse. *International Journal of Human-Computer Studies*, 67(10):887–902, 2009.

[58] D. Huynh, S. Mazzocchi, and D. Karger. Piggy bank: Experience the semantic web inside your web browser. *Web Semant.*, 5(1):16–27, 2007.

[59] D. F. Huynh, D. R. Karger, and R. C. Miller. Exhibit: lightweight structured data publishing. In *WWW '07: Proceedings of the 16th international conference on World Wide Web*, pages 737–746, New York, NY, USA, 2007. ACM.

[60] D. F. Huynh, R. C. Miller, and D. R. Karger. Potluck: semi-ontology alignment for casual users. In *Proceedings of the 6th international The semantic web and 2nd Asian conference on Asian semantic web conference*, ISWC'07/ASWC'07, pages 903–910, Berlin, Heidelberg, 2007. Springer-Verlag.

[61] D. F. Huynh, R. C. Miller, and D. R. Karger. Potluck: Data mash-up tool for casual users. *Web Semantics: Science, Services and Agents on the World Wide Web*, 6(4):274–282, 2008.

[62] D. Iakovidis and C. Smailis. Efficient semantically-aware annotation of images. In *Imaging Systems and Techniques (IST), 2011 IEEE International Conference on*, pages 146–149, may 2011.

[63] D. il Han, S.-B. Ha, and H.-J. Choi. Fox service: An implementation case of ontology-based search agent in mobile environments. In *Mobile Data Management, 2006. MDM 2006. 7th International Conference on*, page 85, may 2006.

[64] R. D. Johnson, S. Hornik, and E. Salas. An empirical examination of factors contributing to the creation of successful e-learning environments. *International Journal of Human-Computer Studies*, 66(5):356–369, 2008.

[65] J. Jovanovic, D. Gasevic, C. Torniai, S. Bateman, and M. Hatala. The social semantic web in intelligent learning environments: state of the art and future challenges. *Interactive Learning Environments*, 17(4):273–309, 2009.

[66] L. Kagal, C. Hanson, and D. Weitzner. Using dependency tracking to provide explanations for policy management. In *Policies for Distributed Systems and Networks, 2008. POLICY 2008. IEEE Workshop on*, pages 54–61, june 2008.

[67] S. M. M. M. Kai Petersen, Robert Feldt. Systematic mapping studies in software engineering. In *International Conference on Evaluation and Assessment in Software Engineering (EASE)*, 2008.

[68] K. Kaljur and N. E. Fuchs. Verbalizing owl in attempto controlled english. In *In Proceedings of OWLED07*, 2007.

[69] V. B. Kampenes, T. Dybå, J. E. Hannay, and D. I. K. Sjøberg. A systematic review of quasi-experiments in software engineering. *Inf. Softw. Technol.*, 51(1):71–82, Jan. 2009.

[70] D. R. Karger, K. Bakshi, D. Huynh, D. Quan, and V. Sinha. Haystack: A customizable general-purpose information management tool for end users of semistructured data. In *In CIDR*, 2005.

[71] E. Kaufmann and A. Bernstein. Evaluating the usability of natural language query languages and interfaces to semantic web knowledge bases. *Web Semantics: Science, Services and Agents on the World Wide Web*, 8(4):377–393, 2010.

[72] E. Kaufmann, A. Bernstein, and L. Fischer. Nlp-reduce: A "naive" but domain-independent natural language interface for querying ontologies. 2007.

[73] B. Kitchenham and S. Charters. Guidelines for performing Systematic Literature Reviews in Software Engineering. Technical Report EBSE 2007-001, Keele University and Durham University Joint Report, 2007.

[74] B. Kitchenham, S. Pfleeger, L. Pickard, P. Jones, D. Hoaglin, K. El Emam, and J. Rosenberg. Preliminary guidelines for empirical research in software engineering. *Software Engineering, IEEE Transactions on*, 28(8):721–734, aug 2002.

[75] B. Kitchenham, R. Pretorius, D. Budgen, O. Pearl Brereton, M. Turner, M. Niazi, and S. Linkman. Systematic literature reviews in software engineering a tertiary study. *Information and Software Technology*, 52(8):792–805, 2010.

[76] B. A. Kitchenham, T. Dybå, and M. Jørgensen. Evidence-based software engineering. In *ICSE*, pages 273–281, 2004.

[77] S. Lee, T. D. Wang, N. Hashmi, and M. P. Cummings. Bio-steer: A semantic web workflow tool for grid computing in the life sciences. *Future Generation Computer Systems*, 23(3):497–509, 2007.

[78] S.-S. Lee and H.-S. Yong. Ontosonomy: Ontology-based extension of folksonomy. In *Semantic Computing and Applications, 2008. IWSCA '08. IEEE International Workshop on*, pages 27–32, july 2008.

[79] J. Lehmann and L. Bühmann. Autosparql: Let users query your knowledge base. In G. Antoniou, M. Grobelnik, E. Simperl, B. Parsia, D. Plexousakis, P. De Leenheer, and J. Pan, editors, *The Semantic Web: Research and Applications*, volume 6643 of *Lecture Notes in Computer Science*, pages 63–79. Springer Berlin / Heidelberg, 2011.

[80] B. Liu, H. Chen, and W. He. Deriving user interface from ontologies: a model-based approach. In *Tools with Artificial Intelligence, 2005. ICTAI 05. 17th IEEE International Conference on*, pages 6 pp. –259, 16-16 2005.

[81] H.-Z. Liu, H. Bao, J.-H. Yu, and D. Xu. An ontology-based architecture for distributed digital museums. In *Machine Learning and Cybernetics, 2005. Proceedings of 2005 International Conference on*, volume 1, pages 19–26, aug. 2005.

[82] Z. Liu, L. Huang, and D. Xu. Research on semantic retrieval system for high-speed railway knowledge based on ontology. In *Proceedings of the 2008 ISECS International Colloquium on Computing, Communication, Control, and Management - Volume 01*, pages 303–307, Washington, DC, USA, 2008. IEEE Computer Society.

[83] N. Loutas, L. Giantsiou, A. Simov, V. Peristeras, and K. Tarabanis. A tool for annotating services with domain specific semantics. In *Semantic Computing, 2008 IEEE International Conference on*, pages 448–455, aug. 2008.

[84] J. A. Macías and P. Castells. Providing end-user facilities to simplify ontology-driven web application authoring. *Interacting with Computers*, 19(4):563–585, 2007.

[85] C. D. Maio, G. Fenza, V. Loia, and S. Senatore. Hierarchical web resources retrieval by exploiting fuzzy formal concept analysis. *Information Processing and Management*, (0), 2011.

[86] A. Miles, J. Zhao, G. Klyne, H. White-Cooper, and D. Shotton. Openflydata: An exemplar data web integrating gene expression data on the fruit fly drosophila melanogaster. *Journal of Biomedical Informatics*, 43(5):752–761, 2010.

[87] W. Min, C. Wei, and C. Lei. Research of ontology-based adaptive learning system. In *Computational Intelligence and Design, 2008. ISCID '08. International Symposium on*, volume 2, pages 366–370, oct. 2008.

[88] J. A. M. narro Gimenez, M. E. na Aranguren, R. M. Béjar, J. T. Fernández-Breis, and M. Madrid. Semantic integration of information about orthologs and diseases: The ogo system. *Journal of Biomedical Informatics*, (0), 2011.

[89] J. Nielsen and T. K. Landauer. A mathematical model of the finding of usability problems. In *Proceedings of the INTERACT '93 and CHI '93 conference on Human factors in computing systems*, CHI '93, pages 206–213, New York, NY, USA, 1993. ACM.

[90] B. Nowack. Confoto: Browsing and annotating conference photos on the semantic web. *Web Semantics: Science, Services and Agents on the World Wide Web*, 4(4):263–266, 2006.

[91] B. Nowack. Paggr: Linked data widgets and dashboards. *Web Semantics: Science, Services and Agents on the World Wide Web*, 7(4):272–277, 2009.

[92] E. Oren. Semperwiki: a semantic personal wiki. In *In Proc. of 1st WS on The Semantic Desktop*, 2005.

[93] N. Partarakis, C. Doulgeraki, A. Leonidis, M. Antona, and C. Stephanidis. User interface adaptation of web-based services on the semantic web. In *Proceedings of the 5th International on ConferenceUniversal Access in Human-Computer Interaction. Part II: Intelligent and Ubiquitous Interaction Environments*, UAHCI '09, pages 711–719, Berlin, Heidelberg, 2009. Springer-Verlag.

[94] H. Paulheim. Ontologies for user interface integration. In *The Semantic Web – ISWC 2009: 8th International Semantic Web Conference, Chantilly, VA, USA*, pages 973–981. Springer Berlin / Heidelberg, 2009.

[95] H. Paulheim and F. Probst. Ontology-enhanced user interfaces: A survey. *International Journal on Semantic Web and Information Systems (IJSWIS)*, 6:36–59, 2010.

[96] A. Penarrubia, A. Fernandez-Caballero, P. Gonzalez, F. Botella, A. Grau, and O. Martinez. Ontology-based interface adaptivity in web-based learning systems. In *Advanced Learning Technologies, 2004. Proceedings. IEEE International Conference on*, pages 435 – 439, aug.-1 sept. 2004.

[97] K. Petersen. Measuring and predicting software productivity: A systematic map and review. *Inf. Softw. Technol.*, 53:317–343, April 2011.

[98] M. Ponnada and N. Sharda. Model of a semantic web search engine for multimedia content retrieval. In *Computer and Information Science, 2007. ICIS 2007. 6th IEEE/ACIS International Conference on*, pages 818–823, july 2007.

[99] L. Qian, X. Hong, W. Dasheng, R. Lei, and M. Cuixia. Ssoa-e: Research on semantic service oriented architecture for education information system integration. In *IT in Medicine Education, 2009. ITIME '09. IEEE International Symposium on*, volume 1, pages 184–189, aug. 2009.

[100] D. A. Quan and R. Karger. How to make a semantic web browser. In *WWW '04: Proceedings of the 13th international conference on World Wide Web*, pages 255–265, New York, NY, USA, 2004. ACM.

[101] J. J. Randolph. A guide to writing the dissertation literature review. *Practical Assessment, Research, and Evaluation*, 14(13), 2009.

[102] M. Rico, D. Camacho, and O. Corcho. Personalized handling of semantic data with mig. In *Database and Expert Systems Application, 2009. DEXA '09. 20th International Workshop on*, pages 64–68, 31 2009-sept. 4 2009.

[103] N. Roy, K. Brooks, and C. Julien. Usability of semantic web for enhancing digital living experience. In *Consumer Communications and Networking Conference (CCNC), 2010 7th IEEE*, pages 1–6, jan. 2010.

[104] S. Schaffert. Ikewiki: A semantic wiki for collaborative knowledge management. In *Enabling Technologies: Infrastructure for Collaborative Enterprises, 2006. WETICE '06. 15th IEEE International Workshops on*, pages 388–396, june 2006.

[105] A. Schmidt. Ontology-based user context management: The challenges of imperfection and dynamics. In *International Conference on Ontologies, Databases and Applications of SEmantics (ODBASE 2006), On the Move Federated Conferences (OTM 2006), Montpellier*, volume 4275 of *Lecture Notes in Computer Science*, pages 995–1011. Springer, 2006.

[106] m. c. schraefel, D. A. Smith, A. Owens, A. Russell, C. Harris, and M. Wilson. The evolving mspace platform: leveraging the semantic web on the trail of the memex. In *HYPERTEXT '05: Proceedings of the sixteenth ACM conference on Hypertext and hypermedia*, pages 174–183, New York, NY, USA, 2005. ACM.

[107] M. Shaw. Writing good software engineering research papers: minitutorial. In *Proceedings of the 25th International Conference on Software Engineering*, ICSE '03, pages 726–736, Washington, DC, USA, 2003. IEEE Computer Society.

[108] B. Shen, M. Yao, Z. Wu, Y. Zhang, and W. Yi. Ontology-based association rules retrieval using protege tools. In *Data Mining Workshops, 2006. ICDM Workshops 2006. Sixth IEEE International Conference on*, pages 765–769, dec. 2006.

[109] Sheng-Yuan and Yang. Ontoportal: An ontology-supported portal architecture with linguistically enhanced and focused crawler technologies. *Expert Systems with Applications*, 36(6):1014–0157, 2009.

[110] S. Shishehchi, S. Banihashem, and N. Zin. A proposed semantic recommendation system for e-learning: A rule and ontology based e-learning recommendation system. In *Information Technology (ITSim), 2010 International Symposium in*, volume 1, pages 1–5, june 2010.

[111] D. Sonntag and P. Heim. A constraint-based graph visualisation architecture for mobile semantic web interfaces. In *Proceedings of the semantic and digital media technologies 2nd international conference on Semantic Multimedia*, SAMT'07, pages 158–171, Berlin, Heidelberg, 2007. Springer-Verlag.

[112] D. Sonntag and P. Heim. Semantic graph visualisation for mobile semantic web interfaces. In *Proceedings of the 30th annual German conference on Advances in Artificial Intelligence*, KI '07, pages 506–509, Berlin, Heidelberg, 2007. Springer-Verlag.

[113] S. Straus. *Evidence-based medicine: how to practice and teach EBM.* Elsevier/Churchill Livingstone, 2005.

[114] I.-F. Toma. Information retrieval using ontosense querying and ontological indexing. In *Computer Sciences and Convergence Information Technology (ICCIT), 2010 5th International Conference on*, pages 383–387, 30 2010-dec. 2 2010.

[115] P. H. R. Unit. Critical appraisal skills programme (casp). http://www.phru.nhs.uk/casp/casp.htm.

[116] V. Venkatesh and H. Bala. Technology acceptance model 3 and a research agenda on interventions. *Decision Sciences*, 39(2):273–315, 2008.

[117] V. Venkatesh and F. D. Davis. A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Manage. Sci.*, 46:186–204, February 2000.

[118] M. Völkel, M. Krötzsch, D. Vrandecic, H. Haller, and R. Studer. Semantic wikipedia. In *WWW '06: Proceedings of the 15th international conference on World Wide Web*, pages 585–594, New York, NY, USA, 2006. ACM.

[119] C. Wang, M. Xiong, Q. Zhou, and Y. Yu. PANTO: A portable natural language interface to ontologies. In *The Semantic Web: Research and Applications*, volume 4519 of *Lecture Notes in Computer Science*, pages 473–487. Springer Berlin / Heidelberg, 2007.

[120] G. T. Wang, P. C.-Y. Sheu, F. Xie, H. Gong, D. Deng, S. Wang, and J. Hu. Integrating semantic web services for declarative accesses in natural language. In *Multimedia, 2006. ISM'06. Eighth IEEE International Symposium on*, pages 201–208, dec. 2006.

[121] X. Wang, T. Luo, C. Zhang, and W. Liu. An architecture of semantic knowledge system for biosafety. In *Fuzzy Systems and Knowledge Discovery, 2009. FSKD '09. Sixth International Conference on*, volume 2, pages 178–182, aug. 2009.

[122] W. Wysota. Porting graphical user interfaces through ontology alignment. In D. Ryzko, H. Rybinski, P. Gawrysiak, and M. Kryszkiewicz, editors, *Emerging Intelligent Technologies in Industry*, volume 369 of *Studies in Computational Intelligence*, pages 91–104. Springer Berlin / Heidelberg, 2011.

[123] T. Yanagida and H. Nonaka. Architecture for migratory adaptive user interfaces. In *Computer and Information Technology, 2008. CIT 2008. 8th IEEE International Conference on*, pages 450–455, july 2008.

[124] Y. Yang, M.-A. Aufaure, and C. Claramunt. Towards a dl-based semantic user model for web personalization. In *Proceedings of the Third International Conference on Autonomic and Autonomous Systems*, pages 61–, Washington, DC, USA, 2007. IEEE Computer Society.

[125] R. Yin. Case study research: Design and methods. Sage Publications, Inc., 2002.

[126] J. Zaino. Google knowledge graph interview. Available at http://semanticweb.com/google-knowledge-graph-interview_b29172.

[127] C. Zannier, G. Melnik, and F. Maurer. On the success of empirical studies in the international conference on software engineering. In *Proceedings of the 28th international conference on Software engineering*, ICSE '06, pages 341–350, New York, NY, USA, 2006. ACM.

[128] J. Zhao, G. Klyne, and D. Shotton. Building a semantic web image repository for biological research images. In *Proceedings of the 5th European semantic web conference on The semantic web: research and applications*, ESWC'08, pages 154–169, Berlin, Heidelberg, 2008. Springer-Verlag.