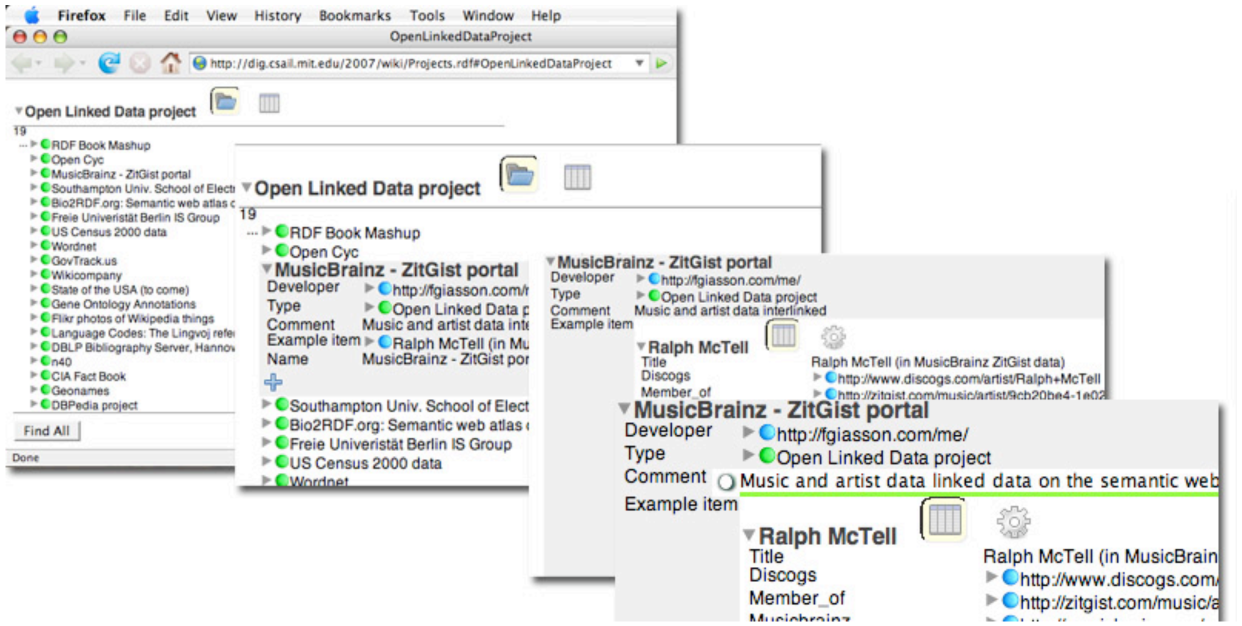
Tabulator Redux: Writing Into the Semantic Web

T Berners-Lee[1], J. Hollenbach[1], Kanghao Lu[1], J. Presbrey[1], E. Pru d'ommeaux[1], mc schraefel[2]
1. MIT CSAIL, Cambridge, MA, USA
2. Electronics and Computer Science, University of Southatmpton, UK
{timbl, eric} @w3.org; {prebrey, mc} @csail.mit.edu


Firefox File Edit View History Bookmarks Tools Window Help
OpenLinkedDataProject
http://dig.csail.mit.edu/2007/wiki/Projects.rdf#OpenLinkedDataProject
Open Linked Data project
RDF Book Mashup
Open Cyc
MusicBrainz - ZitGist portal
Southampton Univ. School of Elect
Bio2RDF.org: Semantic web atlas
Freie Universität Berlin IS Group
US Census 2000 data
Wordnet
GovTrack.us
Wikicompany
State of the USA (to come)
Gene Ontology Annotations
Flikr photos of Wikipedia things
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Open Linked Data project
Music and artist data interlinked
Ralph McTell
Title
Discogs
Member_of
Ralph McTell (in MusicBrainz ZitGist data)
http://www.discogs.com/artist/Ralph+McTell
Music and artist data linked data on the semantic web

Figure 1. The Tabulator. The first frame shows the Tabulator with an RDF source, the Open Linked Data Project open. The second frame shows information within that source expanded, the third frame shows another source within that source expanded, and finally, the last frame shows that the label of that source has been edited from "Music and artist data interlinked" to "Music and artist data linked on the Semantic Web"

ABSTRACT

A first category of Semantic Web browsers were designed to present a given dataset (an RDF graph) for perusal, in various forms. These include mSpace, Exhibit, and to a certain extent Haystack. A second category tackled mechanisms and display issues around linked data gathered on the fly. These include Tabulator, Oink, Disco, Open Link Software's Data Browser, and Object Browser. The challenge of once that data is gathered, how might it be edited, extended and annotated has so far been left largely unaddressed. This is not surprising: there are a number of steep challenges for determining how to support editing information in the open web of linked data. These include the representation of both the web of documents and the web of things, and the relationships between them; ensuring the user is aware of and has control over the social context such as licensing and privacy of data being entered, and, on a web in which anyone can say anything about anything, helping the user intuitively select the things which they actually wish to see in a given situation. There is also the view update problem: the difficulty of reflecting user edits back through functions used to map web data to a screen presentation. In the latest version of the Tabulator project, described in this paper we have focused on providing the write side of the readable/writable web.

Our approach has been to allow modification and addition of information naturally within the browsing interface, and to relay changes to the server triple by triple for least possible brittleness (there is no explicit 'save' operation). Challenges which remain include the propagation of changes by collaborators back to the interface to create a shared editing system. To support writing across (semantic) Web resources, our work has contributed several technologies, including a HTTP/SPARQL/Update-based protocol between an editor (or other system) and incrementally editable resources stored in an open source, world-writable 'data wiki'. This begins enabling the writable Semantic Web.

Categories and Subject Descriptors
H.5.4 Hypertext/Hypermedia; H.5.2 User Interfaces

General Terms
Documentation, Performance, Design, Security, Human Factors.

Keywords
Tabulator, semantic web, read/write, provenance.

1. INTRODUCTION

While the Semantic Web has been developed much as a data integration technology for the last few years, it has lacked an essential element which the hypertext WWW had from the start: the immediate gratification for information providers of seeing the results of their efforts on a screen. The viral spread of the HTML web was largely powered by the process of seeing someone else's web page, viewing the source, copying it with small changes, and then having one's own page to show off to others immediately. However, the first few years of semantic web development focused on back-end technologies. What Semantic web data was produced has been largely consumed off-line, and not generally available to others. Worse still, this mode of working has left the 'web' out of 'Semantic Web': the identifiers used, while URIs, have not been URIs which could be dereferenced to provide useful information.

Recently, collections of offline or zipped RDF data have increasingly been replaced by Linked Data. Linked Data is data using RDF technology that (i) uses HTTP URIs to denote things; (ii) provides useful information about a thing at that thing's URI; and (iii) includes in that information other Linked Data URIs.

The Tabulator [4] was originally written as a linked data browser, designed to provide the ability to navigate the web of linked things without any domain-specific programing by the user or the information provider. It has the inherent knowledge of a few common global concepts such as time and geographical location to give it the power of typical Web 2.0 applications such as on-the-fly mapping and/or calendar mashups in those dimensions. Using the Tabulator, anyone putting up, for example, a personal FOAF [6] file, can see their own information on the screen, and follow links from it to the FOAF descriptions of their friends, not to mention their publications and projects. They become part of an open social network. Since the inception of the Tabulator project, a number of similar data browsers have emerged, including Oink[13] Open Link Software's Data Browser [16], Object Browser [15] and also a growing number of linked data projects [14].

While these developments have been satisfying, the authors were concerned that the a major potential of the system was unimplemented: the web of things, like much of the web of documents, was a read-only web from the point of view of the user. Given the goal of making the web in general a read-write space, surely it was important that a linked data application allow editing as well as browsing. Adding write functionality, however, introduced a number of technical and user interaction design challenges.

One challenge, faced by the read-only Tabulator and exacerbated by the read-write requirement, is that the semantic web provide an extra level of abstraction -- the graph of connected things -- above the web of documents which the web browser user is familiar with. Those features which complicate things by introducing dependencies or connections between otherwise clean architectural layers we refer to as "Level-breakers". We explain why they are needed to allow operation in both spaces where necessary, for social reasons and in case of error. Another challenge is to enable the selection, from an unbounded web of which the system only aware of a small part, of relationships and fields with which the user might express themselves. Also, there is the View Update problem making it less than straightforward to understand what affect and on which RDF document is implied by a given user change to the display.

We will present and motivate these choices, and describe the design and the underlying network protocol and sofware architecture. We will describe a 'data wiki' space that allows remote editing, and the technology used to support it on the server side.

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2. MOTIVATION: Web of documents vs Graph of things

Let us explore some of the challenges behind writing in the Semantic Web. The Semantic Web is two structures, at different levels. There is a space, we call here the 'web', of directed, untyped links between documents, and there is a space we call here the 'graph', of directed, typed of relationships between the things described by the documents. The goal of the project is that the user of the interface should work effectively with co-workers by exploring, analyzing, and collaboratively co-authoring the shared graph of knowledge. We do this in a domain-independent way so that the tool can be used on new fields without programming.

Primarily, users read aggregated information in the graph of interest, ignoring the fact that the data about them may have been assimilated from many sources, possibly with inference. The original tabulator experience demonstrated that secondarily (but importantly) readers must also be able to determine the source documents, and so understand the provenance of the data. The reader can then ask questions such as: Who wrote this? Who is maintaining it? Can I trust it? May I re-use it? and related social questions. These attributes follow from the source of the data. Just as, to trust a document on the web, one peeks at the domain name of the web site, so to trust a statement in the graph, one peeks at the URI of (and metadata about) the document. (We use the term document, though the source may be the sort of thing more often refered to as a store, and may be accessed using SPARQL rather than a simple HTTP dereferencing. The same social aspects of the information apply in either case.)

This peeking between levels breaks the consistency of the user interface which would have been possible at a single level. Simultaneously examining the data and the source of the data produces a small but necessary inconsistency in the user interface.

This level-breaking is also necessary to make errors understandable. Just as, when a web error occurs in a web browser, the user checks the URI and may check the network connectivity to the host, so the reader at the graph level must be able to to understand what document or network operation produced an error. A strength of web browsers, when compared with many distributed systems built of RPC components, is that they allow the user to understand the nature of network errors. We therefore assumed that an editor of the graph must allow users to understand the nature of errors at the document level and below. One must be able to distinguish, for example, between data which is missing in a file, files which have syntax errors, and network errors which prevent us reading them at all.

The tabulator represents the document layer by coloured balls near each concept. The color of the ball indicates the state (unfetched, fetching, ok, error) of documents holding information about the concept. Clicking or hovering over the balls allows more interaction, and a cogwheel 'under the hood' icon allow access to details of HTTP transactions, parsing, etc in case the user needs to explore further.

2.1 The Writing Process

Whenconsidering writing, we expect the user to have social concerns beyond and complimentary to those of reading: Who will make sure this data is stored persistently? Who will be able to read it? Will they be allowed to re-use it, and if so under what terms? The challenge is to ensure that these questions are answerable, but while providing the least possible distraction from the primary purpose of the system.

Though the graph is an aggregation of many graphs from different sources, a simple design of a semantic web editor would be to allow the user to edit one graph at a time. This would obviate the need for connections betwen graphs and documents. Several single graph editors exist including RDFAuthor[21] and IsaViz [17]. We considered two ways to apply this working model. One was the model in which a given single document is selected for editing, and changes are only allowed to be made to that graph of that document. The interface becomes a single document editor, effectively like an HTML document editor such as Amaya [2] in normal editing mode. Another way is to allow the entire graph to be browsed in a read only mode, but annotations made on it and stored on a specific annotation document. This is like the Amaya browser operating in annotation mode. Both modes are evidently useful, and will be considered for future work, but did not, we feel, meet the goal of allowing the user to operate at the abstract level of the giant global graph.

Neither single-graph solution allows the granularity necessary for the social questions of understanding the provenance and controlling the destiny of data; nor do they scale across a web where anyone must be able to buy, rent, borrow or be given storage space under all kinds of arrangements in an open market. We decided to allow users to edit data, even if derived from multiple sources, as simply as if it were a single graph, making changes to different documents throughout the web.

The interface to support this approach must therefore determine where in the web to store a user's addition to the graph. The algorithm we chose for deciding where to store a triple is as follows:

- When a triple is modified, the new is stored in place of the old.
- When a triple is added, it is stored in the same place as the triple immediately above it in the property/value list. Successive additions with the same subject will be consistently written to the same place.
- If a statement is added to an item which has no other statements, if it has a URI like x#y where x is the URI of an editable document, then the triple is added to that document.

In general when creating a new project from scratch, a user must be able to define a new data file and its social properties. Currently, 'user generated content' web sites such as Google Groups, or Facebook, provide certain specific types of policy to meet the given application. Other projects (PAW [8][9], W3C ACL[22]) explore the explicit expression of policies by users. The present work, though, does not provide such facilities, concentrating for now on the editing support. Avoiding the complexities of access control in this version, and out of interest in the wiki model of open collaboration, we chose to open an experimental area of URI space, as a form of data wiki 0[5]. This is a space of data documents which anyone may edit as linked data using the Tabulator or compatible client.

As a test site for Tabulator, for example, within the data wiki URI space, any URI starting with http://dig.csail.mit.edu/2007/wiki identifies a document which is deemed to exist. A fetch to a document which has not been previously stored returns an empty RDF document, flagged editable by an HTTP header. Any data added to such a document causes the actual file to be created to hold the data. looking up for example, http://dig.csail.mit.edu/2007/wiki/foo/fruit#Apple, if http://dig.csail.mit.edu/2007/wiki/foo/fruit does not exist, will return no error, and an item 'Apple' with no data. Adding information about Apple, such that it was a Class, would cause the directory foo and hte file fruit to be created, and a triple `<http://dig.csail.mit.edu/2007/wiki/foo/fruit#apple> rdf:type rdfs:Class.` stored in it.

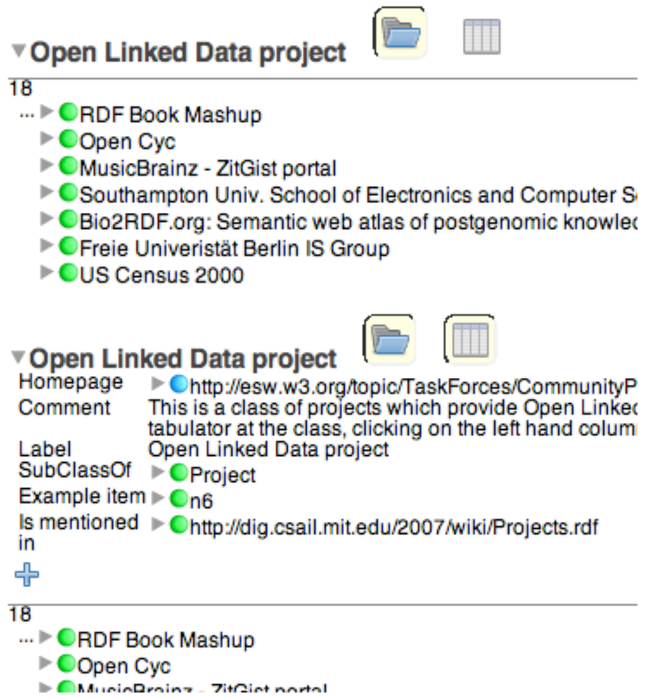
3. TABULATOR INTERFACES

To review the basic interfaces provided by the tabulator for editing, we recall that it is is designed to support two interconnected user modes of operation, the exploration to see what information is available, and the gathering of similar subgraph patterns into tables for analysis typical of tabular applications such as spreadsheets and financial packages. The exploration is catered to by a mode in which a given thing is presented using a table of predicate/object pairs. In the case that the object is something about which more is known, the user may recursively open a nested view of its property objects in turn. This nested hierarchical form we refer to as outline mode (see Figure 1), by analogy with outline writing systems. This is strictly a tree view, but like many trees views is used for what is in fact a graph, and the same node can in principle be found more than once. The icons chosen mimic the (Mac OS X) nested directory interface, seeking an analogy with tree-like navigation aids in web sites which actually have many cross-links, and hierarchical file systems which have soft links.

The user, then, explores sources by opening up related things, occasionally refocusing by restarting a new tree at any given point. The jump to analysis mode is made by selecting a number of fields in outline mode, and pressing a "Find All" button. The linked data graph is then searched for subgraphs matching the given fields. The results form a table, and, if geospatial or time coordinates are include in the columns, a map or a timeline respectively. The jump back is made by selecting any item in the analysis display and opening as a new outline mode display.

Note that whether exploring under user control in outline mode or performing a graph-matching query, the Tabulator store looks up the URIs of any objects which are opened in outline view, or matched as part of a subgraph matching algorithm. It also looks up any property and class, recursively, as ontologies help with inference and user interface. All the data retrieved in this process if kept in the local store.

The description of outline mode above is a slight simplification. In fact, at each level, various styles of predicate/object table may be available. These are called *panes*. If more than one is available then they are stacked vertically and each may be turned on an off by icon-decorated buttons. If only one is available, then no icons are shown (see Figure 2).



▼Open Linked Data project

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... ▶ RDF Book Mashup
▶ Open Cyc
▶ MusicBrainz - ZitGist portal
▶ Southampton Univ. School of Electronics and Computer S
▶ Bio2RDF.org: Semantic web atlas of postgenomic knowle
▶ Freie Univeristät Berlin IS Group
▶ US Census 2000

▼Open Linked Data project

Homepage	▶ http://esw.w3.org/topic/TaskForces/CommunityP
Comment	This is a class of projects which provide Open Linke tabulator at the class, clicking on the left hand colum
Label	Open Linked Data project
SubClassOf	▶ Project
Example item	▶ n6
Is mentioned in	▶ http://dig.csail.mit.edu/2007/wiki/Projects.rdf

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... ▶ RDF Book Mashup
▶ Open Cyc

Figure 2. On selecting the predicate/object list pane, it is stacked above the already open pane.

A class has a special pane to list instances. A document may have panes for inspecting the network transactions involved in fetching it, its human-readable content, or its RDF content reserialized. Other user interfaces for exploration used elsewhere include a circles-and-arrows graph (IsaViz, Foafnaut, Object browser, etc), which tend to be insufficiently compact on the screen for practical quantities of data and property linked predicate/object tables without outlining Oink, which tabulator supports as a special case. The former could be used for selection of a subgraph query, whereas the latter could not as only the arcs from a given node are available on the screen at one time.

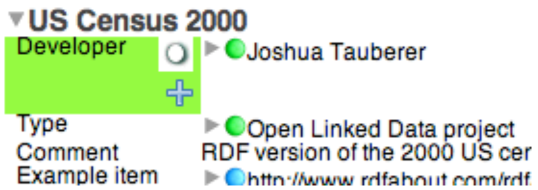
Other modes of analyzing similar datasets are many and varied, and include the faceted browser of mSpace [20], Exhibit [7] slideshows, photo contact sheets, and multidimensional visualizations in the style of Tufte. These styles could all be used just as well as the table, map and timeline modes of tabulator, could link back just as easily to other start new explorations, and indeed could be added as alternative views.

3.1 Types of Editing

Three forms of editing are possible in outline mode: the modification of a object, the addition of a new object with an existing predicate, and the addition of a new predicate/object pair for an existing subject. Consider first the modification of an object cell which contains a literal value. (Non-string datatypes are not currently supported). Cell modification is done by clicking once, or pressing Return, when a cell is highlighted. The field becomes editable. Pressing return (etc) again causes the edit to be committed to the appropriate destination.

3.1.1 Object Selection

If the object of the predicate/object pair in question is not a literal value but something identified by a URI, then it may be selected by name or by drag-and-drop. Following the goal of primarily keeping the user at a the knowledge level rather than the document level, it was felt that URIs should be not be seen or typed. Whenever possible, the tabulator uses an apropriate name for something instead of its URI. (Specifically, any suproperty of rdfs:label is used, with preference for dc:title or foaf:name). To refer to any thing, the user can, then, type in its name. An auto completion dialog box allows selection of the appropriate object without having to type the entire name. An alternative is to drag an object from any object the tabulator view, or the URI icon from any browser navigation bar or tabbed browsing tab. Note that in both these cases, the system must have already have seen the thing in question in some form. In various versions various hacks allowed the expression of a URI explicitly if necessary, but in general the modus operandi is to first get both things visible somewhere before recording a relationship between them.



▼US Census 2000

Developer	▶ Joshua Tauberer
Type	▶ Open Linked Data project
Comment	RDF version of the 2000 US cer
Example item	▶ http://www.rdfabout.com/rdf

Figure 3. Addition of another developer. Selection of the predicate cell causes the plus button to appear.

A special item in the dialog box is "New...". This makes up a URI in the target document local namespace, one which the document does not use already. This creates a new nested property/object list (Figure 3), and the user is free to add more properties. Once a suitable name has been added to its properties, the generated URI is no longer visible. This creation of new nodes in a tree does mimic outline writing aids, as the user can chose to offload knowledge into the graph in any oder as it comes to mind, compared to "Wizard" system of cascading forms, for example, which force a certain sequence.

An attempt is made to restrict the items in the dialog box to be those appropriate for a given situation. As the tabulator currently only has limited OWL inference, without disjoint classes, it is not easy to establish that, say, a given document is not a candidate as a friend of a person. In fact, we note, there are currently few ontologies such as FOAF, which declare classes as being disjoint with other classes in other ontologies.

Consider the addition of a new value to the predicate/object table, using the same predicate. When this is possible, when the source of the existing property/object statement is editable by the user, a blue plus sign shows in the predicate cell whenever it is selected. Clicking on this icon adds a new predicate/object pair, with the same predicate and an object selected by the user as above.

3.1.2 Predicate Selection

Now consider the need to add a new fact to the property/object table, with a predicate not currently in the table. For this purpose, if there is an appropriate destination, a blue plus is displayed on the left at the end of the whole table. Pressing this causes a new pair to be added, prompting with an auto-completion box for the predicate, and then selecting the object as above.

In object-oriented or frame-based systems, of course, there is a finite set of slots for any type of (software) object. This is not so in the Semantic Web, where RDFS and sometimes OWL constraints exist, but "Anyone can say anything about anything" remains effectively true at the user interface. The tabulator can prompt from a list of all the predicares it has encountered in the session,, in data or ontologies, to as with objects, the user must explor enough to equip themseves with the necessary predicates before using them to write. Often there is a large set of valid predicates. Further, some consider it bad from to use RDFS' domain and range constrints, preferring to OWL restrictions that for example the friend of a person should be a person, but not constraining a non-person from having a friend. This may lead to greater re-sue of ontologies, but it also makes it more difficult to unclutter the interface. In future work, we would like to add inference to include awareness of disjoint classes.

An alternative design choice which we considered and, while unimplemented is still appealing, is to provide a form which prompts explicitly for the properties which similar objects in the existing data currently loaded. While the user would always have to be able to escape into use of new predicates, much data is repetitions, and its entry would be optmized for. In an address book, for example, one typically uses a small set of all the very many properties one could in principle record about a person.

3.1.3 Editing in Table Mode

Recall that the table is formed by performing a query for a graph pattern across the graph. Row insertion involves constructing a new subgraph which will match the query template. The destination store for each arc is copied from that of the arc for (arbitrarily) the last row in the table. Therefore, if a table is made from a join of several sources, they can all be updated by adding a new row. The operation of cell value editing, as in outline mode, involves removing a statement and inserting a replacement in the same document.

4. NETWORK PROTOCOL FOR WRITING

Driving the design of the network protocol to support writing has been desire to create a web of editable resources, and to allow the user to naturally interact with the data without having to set up preferences such as 'up-load addresses' or 'publish location' which are very typical of web hosting services. A subgoal therefore was to make the system self-configuring. To this end, we send updates to the URI of the destination document itself. We use two protocols, the standard WevDav [23](not completely implemented at time of writing) and a version of SPARQL/Update [19], the Semantic Web query language, extended to allow update.[1]

An HTTP server may advertise that a given document is editable by sending an HTTP header when the document was fetched. We noticed that servers supporting WebDAV authoring often send a non-standard header "MS-Author-Via: WebDAV". Feeling that one big pile was, as it were, better than two little ones, we adapted this to send "MS-Author-Via: SPARQL" when a server supported incremental update by SPARQL.

Other systems, such as the HTTP PUT method or the WebDAV protocol also communicate using the URI from which the document was read. With these systems, though, a typical editing session involves more or less off-line editing, followed by an explicit save user action. This can result in lost data if the client system crashes or is closed down before the edits can be written back. While offline/sync systems such as IMAP clearly have their advantages when disconnected, we decided to implement a real-time online system with small change granularity. The goal of a user immersed in the community knowledge would ideally allow direct update on all collaborator's screens, and so immediate update was a step in the right direction.

[1] The update extension proposed in SPARUL and SPARQL/UPDATE is not standardized but we derive comfort from the fact that we successfully used the intersection of the two current proposals.

Tabulator's collaborative editing protocol is based on a server-side document store potentially shared by many clients following a strategy of optimistic concurrency. When any edited field loses user focus or is changed and deemed savable, Tabulator uses the URI of the 'appropriate destination' document to be edited as described above. It assembles an update message to send to the document's server. At this point, the modified field is grayed out, and locked for user input, so no conflicting changes can be made before the update process completes. This graying out also serves as feedback to the user that their changes are being saved. Tabulator submits these statements in the body of the POST request to the URI. When an acknowledgment is received from the server (a "200 OK" HTTP response) confirming that the change has been made to the document, the edited field will unlock.

If on the other hand, an error occurs, the user is alerted with a dialog box requiring acknowlegment, and the change in the user interface is backed out. In a collaborative environment the error could be a user-level concurrency error that incompatible changes have been made to the same document. However, network errors, server unavailability, and so on, may also have to be explained to the user. The update message, and un-graying of the field is performed assynchronously so that the user is free to perform more editing, possibly with several modifications pending server acknowledgment.

The protocol builds on HTTP and SPARQL with as little arbitrary design as possible, so as to be as uncontentious as possible, in the hopes of wide adoption. The idea of regarding each file on a web server as being its own SPARQL endpoint is not the typical use, in which a single SPARQL endpoint serves one large stores possible containing many individual graphs from different files. However, it is quite consistent with the SPARQL design. The extensions used for update, INSERT and DELETE take a syntactic form based on the existing CONSTRUCT production, and so are not particularly novel. This update protocol design also inherits useful functionalities of HTTP implemented by the client browser. Document permissions can be implemented and access can be limited as specifically as for any other URI on the web, using the standard HTTP authentication mechanisms.

This is not perfect: it would be nice to distinguish between an empty document and non-existent one in the HTTP response, but we would have to have a way of saying that the 'Not Found' error was not a serious error if you are writing. It is not obvious how many hoops the user should be made to jump though to create a new file, whether just to reference it, or confirm their intentions, or specifically ask to create a new file with a given URI. HTTP PUT could of course be used for creating a new file, though the server does not currently support it.

Also, this approach should be extended into a collaborative system: when concurrent editing occurs, a clash may occur, and the response form the server (or the peer-peer system) be a series of patches from other editiors, which will cause local user roll-back. The roll-back has been implemented, but not the patch distribution protocol.

4.1 Current Implementation

As stated, to explore the social assumptions of a wiki at the graph level, we set up a sandbox for anyone to create new data by deploying a data wiki. Any RDF data field could be uploaded to the wiki, but of course it will be reserialized, losing any comment. The system is designed to integrate very smoothly with a filestore-based web server. thedata is all stored in RDF files. Setting up a read/write access to an arbitrary file should not be complicated.

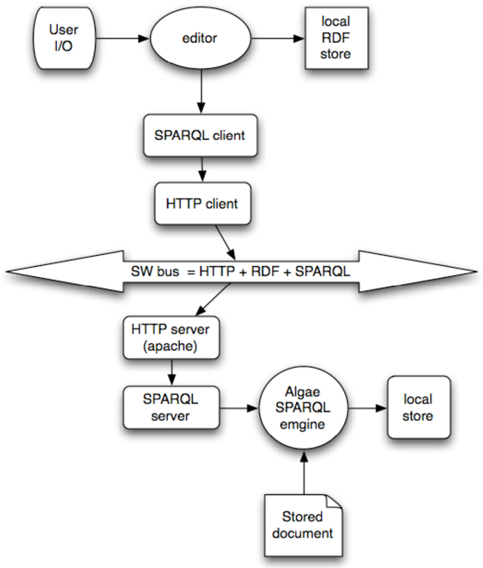


Figure 4. The client side is implemented in the asynchronous Javascript environment of a Firefox extension. A local provenance-aware triple store aches all RDF data seen in the session. When a change is made, the editor uses the SPARQL-Update client

In our implementation (Figure 4) we hold the data in each document in a file in the file system, represented in the data wiki. Since every update request is posted its respective document URI, the server trivially locates the destination of the update request, parses it, and attempts to apply the update. The DIG RDF wiki runs Apache and PHP that parses out the update payload. It instantiates an Algae RDF store, which reads the file's contents, applies the update, and writes the file back to generate the document's revised edition.

5. CHALLENGES / FUTURE WORK

While we have made good progress in enabling real-time editing of semantic web resources, a number of challenges remain that are part of our agenda for Tabulator.

Browser integration. The integration of the tabulator data browser-editor and the Firefox browser posed some technical difficulties due to the assumptions that the Firefox design made. The Firefox browser assumes that one document is displayed in one window. As a matter of security, it makes sure that the URI in the bar always matches that of the page being shown. This user interface guarantee makes no sense when the URIs the user is interested in are those of things in the graph, not items in the web. This is one of the tensions between the user interfaces at the graph and web level.

Updating Information. There are many ways in which the existing implementation needs rounding out to have simply the power that a conventional application: the handling of datatypes, explicit or implicit; the implementation of offline working mode; update using WebDav for those who need to source editable RDF but have ISPs who do not support SPARQL (yet). The table view should have the facilities of a typical spreadsheet. All views should allow update, the map view and the time line view for example should allow the dragging of objects whose coordinates are editable. And so on.

Collaboration. Improving the collaborative aspects of the system could involve the subscription by clients to streams of and changes to any sources which currently affect the display seen by the user. Peer-peer distribution on differences for editing of data between local network neighbors without a common server would be another possibility.

Predicates. We discussed above the need for better selection of predicates and objects for user input. If the number of predicates could be cut down to something of order 10, then a form (as a tabulator pane) could be created for every new object, which would mimic typical applications more easily. Obviously, the provision of forms languages such as Xforms would allow tailored user input experience, but we wanted in this project to push the boundaries of what could be built up from ontologies, with forms seeming to emphasize the application domain boundaries which we had wished to disolve.

Social Policy. In the longer term, we are intersted in adding user interfaces for creating an awareness of policy, in adding workflow actions in the style of Papertrail[3]

UI/Usability. Just as there are two modes of data browsing, exploration and analysis, there are also two modes of development for a user interface. For a user-interface in a well-established field, usability testing is done in order to determine whether the user interaction can in fact be claimed to be optimal, or to elucidate possible areas for improvement unnoticed by the designers. Comparisons are made with comparable solutions to find ways in which the given user interface could possibly be improved. This is analysis mode. The alternative is exploration mode, in which new field is being mapped out. There are few or no comparable systems which perform the same task. The motivation is often personal need of the developers; the list of features requested and possible improvements is huge, and (if open for writing) added to immediately by any new user. There are no claims that the current interface optimal, only that much opportunity exists for improvement. This latter is the development mode of the Tabulator semantic web browser-editor.

Longer term developments we hope to pursue include the prompt update of all users' displays when one user changes the data, to make it a stronger collaborative tool. This will require changes to the network protocols, and an upgrade of the local store to a full Truth Maintenance System. We would like to allow system sheets, possibly in the style of Fresnel (but for editing) to define forms (tabulator panes) appropriate to different data patterns.

6. Conclusion

Recent years have seen an explosion in user-generated content on the web, which can be divided into two categories. On the one hand, the blogs and wikis are human-readable content which thrive by being linked together globally. On the other hand are the social networking sites, where users add relationships between people, but where linking is only site-wide. We set a goal to create an editable data space not limited to a particular domain (not just friends, photos or events), and linked across domains, to break it open into a globally linked system linked across websites; to make it collaboratively editable as a shared store of knowledge and thus to bring about a step change in the power of an individual.

We have shown that live semantic web editor is a non-trivial design challenge, but capable of providing a collaborative editing environment in at a level of abstraction above that of the web of documents: the graph of things. Though the Tabulator prototype lacks some usability features and polish, it demonstrates the feasibility of direct editing of semantic web data across multiple servers and interconnected domains of discourse. It does this adapting many familiar interface metaphors from current hum interface practice. Unlike in object oriented and frame-oriented system, there is no fixed set of slots for each object for the user to fill in. There are no forms: instead, we explored the balance between ontology and existing data to help guide the user when adding more data. Just as semantic web readers need to be aware of the provenance of the data they read, and its social implications, so writers must be aware of the destiny of the data they write - and its social implications.

The system works. Its greatest value we feel is as a basis for other things. We encourage others to experiment with different styles of client and of server built to the same HTTP/SPARQL network protocol. We hope to tackle many of the large set of request for enhancement. A hope is that it will become sufficiently intuitive for, say, a spreadsheet user to use effectively. Already at this stage, though, we feel that the feasibility of this architecture has been conclusively demonstrated. We have resolved a number of design questions. We have created an application-independent architecture in which application-specific features can be smoothly blended. We demonstrate that there is no good reason why the semantic web should not be collaboratively writable, such that the fusion of the ideas of humanity and machine-processable knowledge of machines becomes ever closer.

7. ACKNOWLEDGMENTS

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