Knowledge Gardening as Knowledge Federation

Jack Park

SRI International
Menlo Park, CA
and
Knowledge Media Institute
The Open University
Milton Keynes, UK

Abstract. The term *knowledge gardening*, a contraction of the longer *dynamic knowledge gardening* (DKG), is a direct descendant of Douglas Engelbart's *Dynamic Knowledge Repository* (DKR). A DKR exists as a combination of humans and tools, epistemic communities and the tools they use to aggregate information resources and work products, and to collaborate. We describe TopicSpaces, an open source topic-map-based framework with which the collective hypermedia discourse of epistemic communities is federated. We define hypermedia discourse as the totality of social gestures made by such communities. That is, recorded dialogs, linked, annotated and tagged Web resources, recorded stories, virtually all addressable information resources created anywhere on the Web constitute the range of resources federated. We define federation of resources as the specific merging processes native to topic mapping. We contrast federation with traditional semantic integration processes where artifacts of knowledge are aggregated through processes of selection. Where selection processes involve "weeding" (a gardening process), federation does not perform weeding during the merge process; rather, federation involves including all resources during the merge process; social processes including reputation, trust, and dialog will help determine which resources users find most valuable in their work. TopicSpaces provides a map of the federated territory, user interface tools to facilitate some hypermedia discourse practices, and Web services to interface with other hypermedia discourse tools.

Keywords: topic map, knowledge garden, knowledge federation, subject-centric computing, hypermedia discourse

1 Introduction

We offer a position paper that describes one approach among many to the federation of heterogeneous information resources and world views. Our thesis is that a subject-centric federation is appropriate to the problem of supporting knowledge gardening (also known as *collective sensemaking*—see Section 7) to find solutions to complex and urgent problems. Our work with SRI's Cognitive Assistant that Learns and

Organizes (CALO) project[1] has taught us numerous lessons that support the need to federate heterogeneous world views and information resources. For instance, Park and Cheyer [1] report on the need to federate the personal ontologies of CALO users with the business-oriented ontology that CALO uses internally to maintain semantic interoperability among groups of CALO installations. Our thesis project, titled *Hypermedia Discourse Federation,* explores the technologies and tactics required to federate the work products of several tools of hypermedia discourse together with heterogeneous information resources found on the Web.

In our work, we have adopted the term *knowledge gardening* as a name for the federation processes. This follows Douglas Engelbart's term *Dynamic Knowledge Repository,* which is his name for the combination of people, software tools, and processes as *improvement communities*. In some illustrations of our work, we use the term *knowledge garden* to name our topic map-based Web portal. Our story explores the role of topic maps in the federation of heterogeneous information resources through processes of subject identification and merging different representations of the same subject in the same map. We believe that the maintenance of well-organized information resources can contribute to improvements in knowledge gardening processes, toward improved human dialogue.

This paper is organized as follows. We first review the two elements of hypermedia discourse that we federate through topic maps. They are semantic linking (connecting), and dialogue (sometimes also known as *issue*) mapping. We include social bookmarking as an additional element; while hypermedia discourse[2] centers on *contested* assertions and ideas, knowledge gardening entails the wider range of social activities on the Web. We then review our subject-centric federation, or knowledge gardening approach. We then sketch TopicSpaces, our prototype federation platform. We then introduce the *knowledge gardening* process and close with illustrative examples. Brief references to related work are given where appropriate.

2 Social Bookmarking: Tagging

Tags are associative *reminders*. In the CALO project, tags are the names of projects in which CALO users are engaged. For instance, one typical CALO project is the CALO "platform" itself, a project where CALO developers keep track of the design and development progress on the product. The tag "Platform" would be used by CALO developers as they surf the Web looking for information resources of value to the team. They use that tag with Tagomizer, CALO's social bookmarking application written on top of the topic map engine TopicSpaces [2], [3].

Tagging is part of the larger social gardening repertoire; tags leave *trails* or form *scents* [4] along information foraging [5] paths taken by many. Tagging is part of the *foraging* and *filtering* aspects of knowledge gardening (see Section 7).

While tagging is generally thought to enable the formation of clusters of topics, Brooks and Montanez report some interesting results [6] from experiments with hand-tagged and auto-tagged articles. Using measures of pairwise similarity in the case of

[1] CALO: http://www.ai.sri.com/project/CALO

[2] Hypermedia Discourse: http://kmi.open.ac.uk/projects/hyperdiscourse/

human-tagged articles, they conclude that "tagging does manage to group articles into categories, but that there is room for improvement." They then report on an experiment where they extract, from 500 articles, the three words with the top term frequency – inverse document frequency (TFIDF) score from each article and use those as "auto tags" for each article. They then cluster the auto-tagged articles. They report better and smaller clusters when compared to human-derived tags, and suggest that automated tagging can add great value to search for topics using tags. Our prototype federation platform facilitates human tagging through its Tagomizer application, while a background agent harvests tags automatically from bookmarked Web pages.

Grouping and clustering topics with tags is not the only application for tagging. We continue to discover new applications. For instance, Razavi and Iverson [7] report on a novel approach to using tagging to maintain groups and access control to information resources in their OpnTag[3] project.

3 Semantic Linking

In some sense the entire Semantic Web enterprise is about semantic linking. In the sense discussed here, a narrow definition is taken: semantic linking here refers to the creation of typed connections between *ideas* found in documents on the Web. In that sense, semantic linking is subject-centric by its very nature. In 2001, the Scholarly Ontologies Project at the Knowledge Media Institute began to envision a "complementary infrastructure that is 'native' to the internet, enabling more effective dissemination, debate, and analysis of ideas"[4]. In 1999, three authors [8] proposed that when a new article is to be published, "authors describe the document's main contributions and relationships to the literature using a controlled vocabulary analogous to a metadata scheme (but implemented using a formal ontology), and submit the description to a networked repository." In more recent writing [9], the Cohere project (Figure 1) has been described as an online means where social processes are used to find and annotate ideas on the Web.

[3] OpnTag: http://opntag.net/
[4] ScholOnto: http://kmi.open.ac.uk/projects/scholonto/

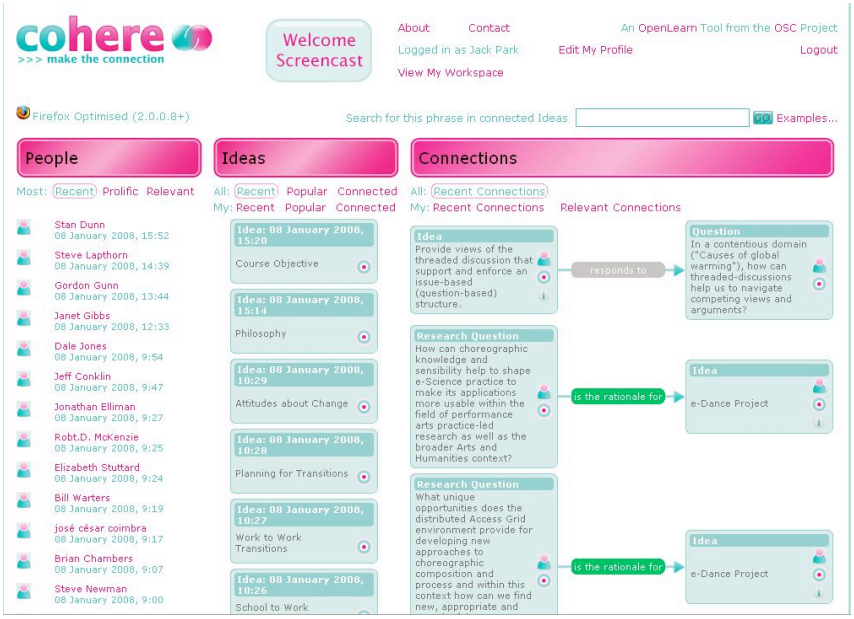

Fig. 1. Cohere[5] semantic linking Web portal

4 Dialogue Mapping

Dialogue mapping provides a common view of a growing structured representation of streams of thoughts [10]. In fact, there are limits to conversation [11] that we illustrate as Figure 2. Starting with a linear collection of thoughts, it is possible to tease out of that collection a starting question followed by statements that answer the question, statements that argue about the answers, and possibly statements that raise new questions.

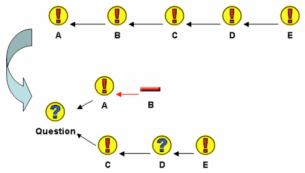

Fig. 2 . Finding structure in streams of thoughts with Compendium

Analyzing a large body of text into such a map is called *issue mapping*[6]. For instance, a recent *OpEd* discussion[7] about *food riots* was mapped by the author as illustrated in Figure 3.

[5] Cohere: http://cohere.open.ac.uk/
[6] Issue mapping: http://cognexus.org/issue_mapping.htm
[7] OpEd: http://www.nytimes.com/2008/04/07/opinion/07krugman.html

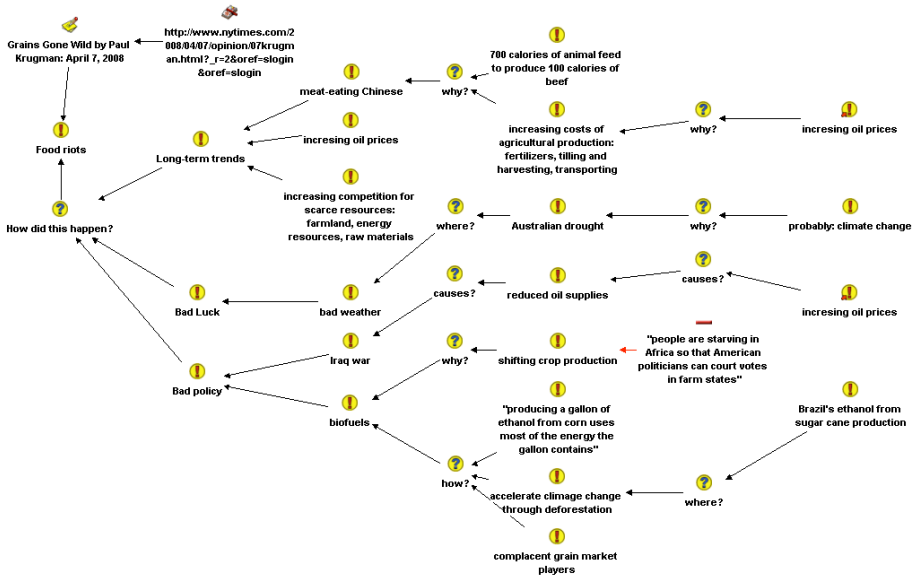

Fig. 3. Finding structure in an OpEd with Compendium

The map reads left to right, starting, essentially, with an opening question. The node "Food riots" leads to the columnist's opening question: "How did this happen?" The columnist provided his own three answers: "Long term trends", "Bad luck", and "Bad policy". From there, it is a matter of picking out questions being asked, finding answers, and identifying any arguments made in the prose. A similar dialogue map would occur if a discussion group was facilitated by a skilled dialogue mapper and similar questions and responses were recorded.

5 Subject-centric Federation

We live in a vast collection of universes of discourse, each centered on different topic domains, many of which overlap and share subjects and concerns. The issue map of the OpEd illustrated in Figure 3 could just as easily have been generated in slightly different forms, each representing a different interpretation by a different analyst. That each is somehow different contributes to heterogeneity in information resources with which we must all cope in our day-to-day and decision-making lives. A goal of our work is to *federate* these heterogeneous resources into a coherent representation with which we believe improved knowledge gardening is afforded.

Consider just one node in our OpEd issue map, the one shown in Figure 3, for which the label reads "700 calories of animal feed to produce 100 calories of beef". That is a specific quote from the OpEd text; it is reasonable to expect that other analysts might pick up the same *claim*, even if placed in a different part of the map's graph structure.

700 calories of animal feed to produce 100 calories of beef

Fig. 4. A *Claim* found in the OpEd and represented in the issue map

Claims such as that are, at once, subject to fact checking, and to *entailed subjects*. Fact checking can be the work of background agents, or the work of the *crowd* engaged in knowledge gardening. Subject entailment goes with the nature of the claim. That is, there is a relationship between animal feed and animals, and both of those two subjects exist in a web of related (entailed) subjects. Consider the simple concept map (Figure 5) of some (but not all) subjects entailed by the node illustrated in Figure 4.

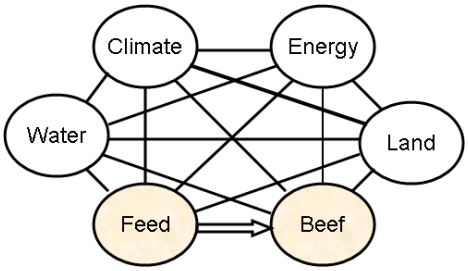

Fig. 5. Subjects entailed by the two subjects "Feed" and "Beef"

By creating a topic map of dialogues, and by including all entailed subjects, we gain a broader means by which the work products of knowledge gardening can be evaluated. By linking into that map each node created by each individual, no matter how that node falls in its native dialogue map structure, we are performing subject-centric federation: we are *bringing together* information resources that are *about* the same subject, and we are connecting those resources to all known to the map resources of the same or related subjects. We do so without editorial bias; we federate regardless of whether or not we agree with claims represented. We leave disagreements to the gardening processes in which the map's users are engaged.

5.1 Related work

Tools that support dialogue mapping include Compendium[8], bCisive[9], TruthMapping[10], and DebateGraph[11]. Compendium and bCisive are desktop tools, while TruthMapping and DebateGraph are online portals.

Mark Klein [19] describes online dialogue mapping on a large scale. He describes the popular communication tools– instant messaging, email, forums, wikis – as facing "serious shortcomings from the standpoint of enhancing collective intelligence". He

[8] Compendium: http://compendium.open.ac.uk/
[9] bCisive: http://bcisive.austhink.com/
[10] TruthMapping: http://truthmapping.com/
[11] DebateGraph: http://debategraph.org/

then goes on to describe the need for maintaining structure in conversations as we discussed in Section 4.

6 A Prototype Subject-centric Federation Platform

TopicSpaces is a servlet-based Web portal provider that includes a subject map, which is a topic map created according to the Topic Maps Reference Model [12]. The platform provides a servlet-driven REST API [13] for Web services, and will later provide a tuplespace agent coordination platform [14] to coordinate harvesting agents on the Web and those included in desktop applications.

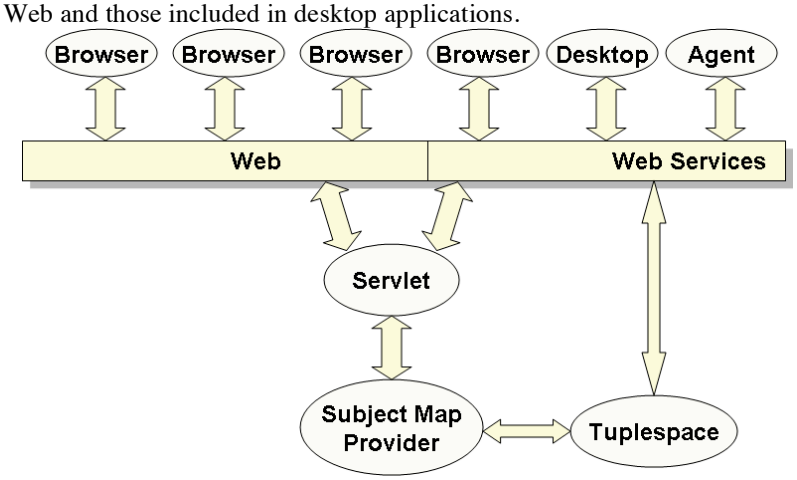

Fig. 6. The TopicSpaces platform architecture

The platform illustrated in Figure 6 anticipates the ability to run *seti@home*-like agent-based harvesting of resources found on the Web. A tuplespace platform [15] provides the necessary agent coordination. For instance, consider the scenario where a user tags a website that is new to the TopicSpaces portal. That new resource is sent to a harvesting agent that can either perform harvesting tasks locally, or post a new harvesting task to the Tuplespace where agents elsewhere on the Internet have authenticated and are waiting for harvesting tasks. A typical harvesting task, well suited to topic-mapped resources is that of the TextRunner[12] process [16], where bodies of text are parsed, not for sentence structure, but for noun and verb phrases from which concept maps are constructed that represent the material being "read" by the agent. The TextRunner approach parses bodies of text into lists of triples of type `{entity, relation, entity}` from which concept maps, later topic maps, can be constructed. We believe that the topic map's attention to the details of subject identity can render this process more accurate; to do so, an iterative process of comparison of the resulting concept maps with their corresponding named topics in a topic map will allow refinement of the concept map before migrating it into the topic map. This will be particularly important in cases where named concepts found by the

[12] TextRunner : http://www.cs.washington.edu/research/textrunner/

TextRunner algorithm are determined to be ambiguous; different entities with the same name create such ambiguities.

6.1 Portals

TopicSpaces is a research platform, one that can support two classes of topic maps portals as illustrated in Figure 7. One class is the *all-in-one* portal where all the context view portals, collaboration portals, and personal workspaces are part of the same software package. TopicSpaces is built like that as a means to explore all issues related to knowledge gardening.

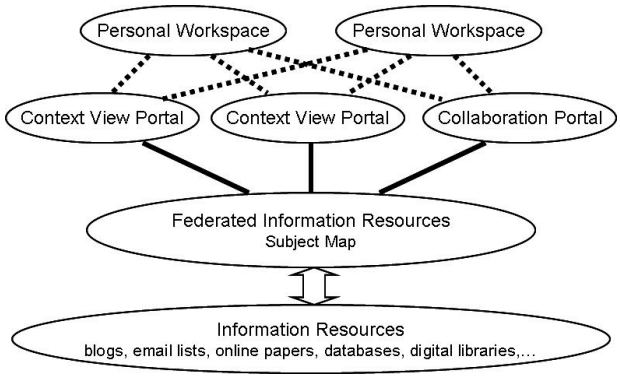

Fig. 7. The TopicSpaces Web portal architecture

A second class of portal separates all the context portals, collaboration portals, and so forth from the subject map itself. Different portals can then be crafted using standard CMS platforms such as Drupal, WordPress, and other popular software products. TopicSpaces can provide Web services to those portals as needed.

6.2 REST Web Services API

What is a REST Web Service? It is simply a means to use URLs as query vehicles by way of a servlet. Web browsers make such requests routinely; type a particular URL into a browser and the server returns the entire Web page in a single HTML string. A Web service would, instead, return a small fragment of HTML, of XML, or Javascript Object Notation (JSON)[13] as requested. Bookmarklets, as used by Tagomizer, del.icio.us, and other social websites, represent a kind of Web service where a short Javascript string embedded in a browser's bookmarks is able to transport information from a Web page to the portal that accepts the Bookmarklet's query. When we say "API", we are specifying that there is a particular *query string* that goes in the URL, and that query string is interpreted by the portal to perform the requested task. Some tasks are to return a requested bit of information, the bookmarks

[13] JSON: http://www.json.org/

associated with a particular tag, say. Other tasks are to update information in the topic map, to add a new bookmark, say.

The TopicSpaces REST API takes the form:

```
<server>/ws/<appname>/<object>/<return>/<data>
```

For instance, asking for a Tagomizer tag in HTML where the tag is "SomeTag" is this query fragment:

```
/ws/tago/tag/html/SomeTag
```

The same query returning the result in JSON is this:

```
/ws/tago/tag/json/SomeTag
```

7 Knowledge Gardening Processes

We open our discussion on knowledge gardening by reviewing related work. That work is embodied in a literature under the subject of *sensemaking*, making sense of complex situations. Thus, *knowledge gardening* is our name for sensemaking.

7.1 Related work

Brenda Dervin's sensemaking methodology [20] is characterized as bridging a situation-outcome gap. A visual imagination suggests similarity to Gowin's Vee [21] (Figure 8) where her situation is modeled as the present state of a learner in terms of conceptual knowledge, the outcome is modeled as the work product of performance, and the gap represents question answering and feedback. Gowin's Vee diagram serves to illustrate the processes of constructivist learning where a focus concept provokes questions which the learner, applying existing personal knowledge, articulates answers, writes reports, and engages in responding to feedback.

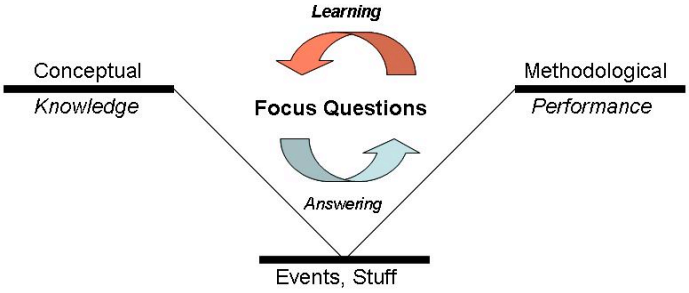

Fig. 8 . Gowin's Vee (after [19])

Sensemaking has been approached from the perspective of surprise, of *expectation failures* [22]. Sensemaking is defined [22] as the deliberate effort to understand events and is typically triggered by unexpected changes or surprises that make a decision maker doubt his prior understanding. The authors [22] further characterize the process as active, building, refining, questioning, and recovering situation awareness. Elements of their "Data-Frame Model of Sensemaking" sketched in their paper are these:

- Recognize and construct a frame
- Perform cycles of elaboration on that frame, adding and filling slots, seeking, inferring and discovering data
- Ask questions of the frame, detecting inconsistencies, judging plausibility, analyzing data quality
- Perform cycles of refactoring, where the process is to seek a new frame that better describes the situation

In the *line of inquiry* framework [23], the sensemaking is facilitated by a framework that embodies theories, questions, information-seeking strategies, evidence and evidence collections, knowledge, assigned investigators, and lower-level lines of inquiry. As suggested in the paper's title, this is a recursive framework. A line of inquiry will spawn subinquiries, each of which is treated as a fully embodied line of inquiry. Elements of the framework are

- Generate theories
- Ask questions
- Seek new information
- Collect evidence
- Gain new knowledge
- Assign investigators
- Spawn subinquiries

Jean-Claude Bradley [24] describes a generalized sensemaking process he calls *Open Notebook Science*. He coined the term to avoid ambiguities associated with the name *Open Source Science*. He describes a process wherein a traditional *lab notebook* is implemented within a wiki platform, and blog entries are used to tell stories about events and findings in the notebook.

Standing by itself as a new class of sensemaking portal is Science X2[14]. The portal provides users with dashboards that consist of unread posts to groups to which the user is subscribed, lists of "signals", "hypotheses", and "forecasts" generated by the user. While we have only a "beginner's" experience with the website, it appears that users post *signals*, an instance of which might be "Topic maps improve sensemaking", and other users form *hypotheses* around such signals and later offer *forecasts*. We view this portal as federation of goal-oriented blogs, tightly coupled through the three classes of artifacts. In some sense, the portal, by virtue of its three specified artifacts, is naturally self-organizing in a subject-centric fashion.

7.2 Our project

As we continue to evolve our tools, and as we use them in our own research, we are beginning to understand, if even to a somewhat naïve level, what so-called *best practices* might look like. We now understand some best practices for tagging, and are just now beginning to practice semantic linking and dialogue mapping. Those best practices exist in the context of the larger *gardening* process. Gardening processes occur within some context, some goal, some working hypothesis or research question.

[14] Science X2: http://sciencex2.org/

We see the process as iteration around and within this sequence:

1. Forage
2. Filter
3. Analyze
4. Synthesize

Foraging and filtering are the information-seeking stages in which combinations of goal-directed search and thematic vagabonding result in discovered information resources. In this stage, one tags the resources for later harvesting. This is the stage where benefits accrue from tagging best practices. In our CALO scenario above, we described the application of a *project-centric* tag *ontology*, the use of predefined tags for specific purposes. We are learning that it is appropriate to use more than one tag for each resource discovered. While CALO prescribed *project-centric* tags, we further prescribe *subject-centric* tags. While reading a particular resource on discovery, take the time to tag the particular actors, relationships, states and other important subjects bound by the resource. This extra work pays large dividends later.

Concurrent with tagging, semantic linking serves as a transition to analysis through partial harvesting and forging semantic connections between ideas harvested from the pages visited. We are able to use the full suite of hypermedia discourse tools in the foraging-filtering stages and in transitioning to analysis [17] and [18]. Figure 9 illustrates how we used Compendium, with a simulated Cohere connection, to organize a literature search related to subject identity.

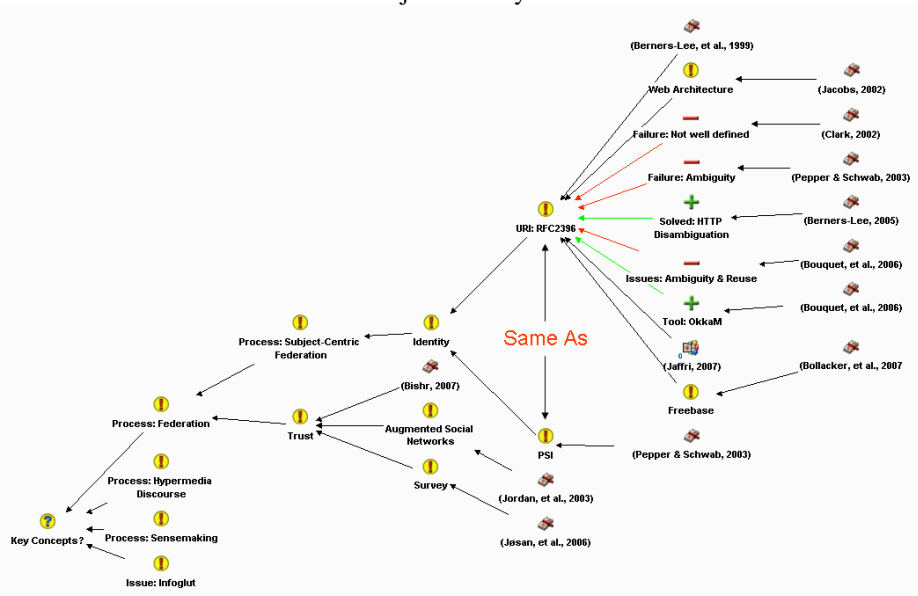

Fig. 9. Using Compendium and Cohere (simulated) to organize a literature review

Reading this issue map from left to right, it organizes the concepts about which our literature review must speak. Toward the right, we begin to tease out of the literature each argument made, and we tie each argument to the specific citation from which it is drawn. The two key concepts were URIs from the Web community and

PSIs from the topic maps community. Our analysis suggests that they behave as the same concept, and we note that through a Cohere-like coherence relation.

The analysis stage includes finding answers to research questions posed at the beginning of the process, and derives new questions to ask and finds their answers—or reports them as targets for future work. In the analysis stage, some assertions made during foraging and filtering – our *Same As* assertion, for instance– may come under close scrutiny by those who do not share the same world views. It is at this point where dialogue mapping services enter the arena and various actors take positions and offer arguments. That's knowledge gardening at work.

8 Discussion

A general outcome of this work for CALO is to provide a Web-based presence that supports knowledge gardening among communities of CALO users, as shown in Figure 10.

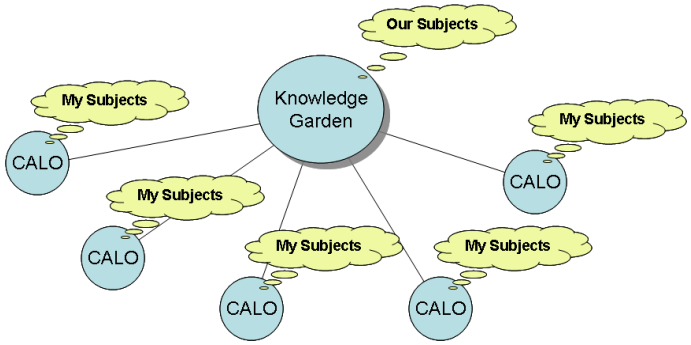

Fig. 10. Topic map-based gardening portal for communities of CALO users

In the work reported here, we have installed an instance of TopicSpaces and we have begun to use it in two different contexts: developing a dashboard platform for CALO, and using it to organize our thesis research, snippets of which have been illustrated here. An allied goal has been to demonstrate the ability to federate communities of CALO users where subjects important to all members of the community are shared and maintained at the Web portal.

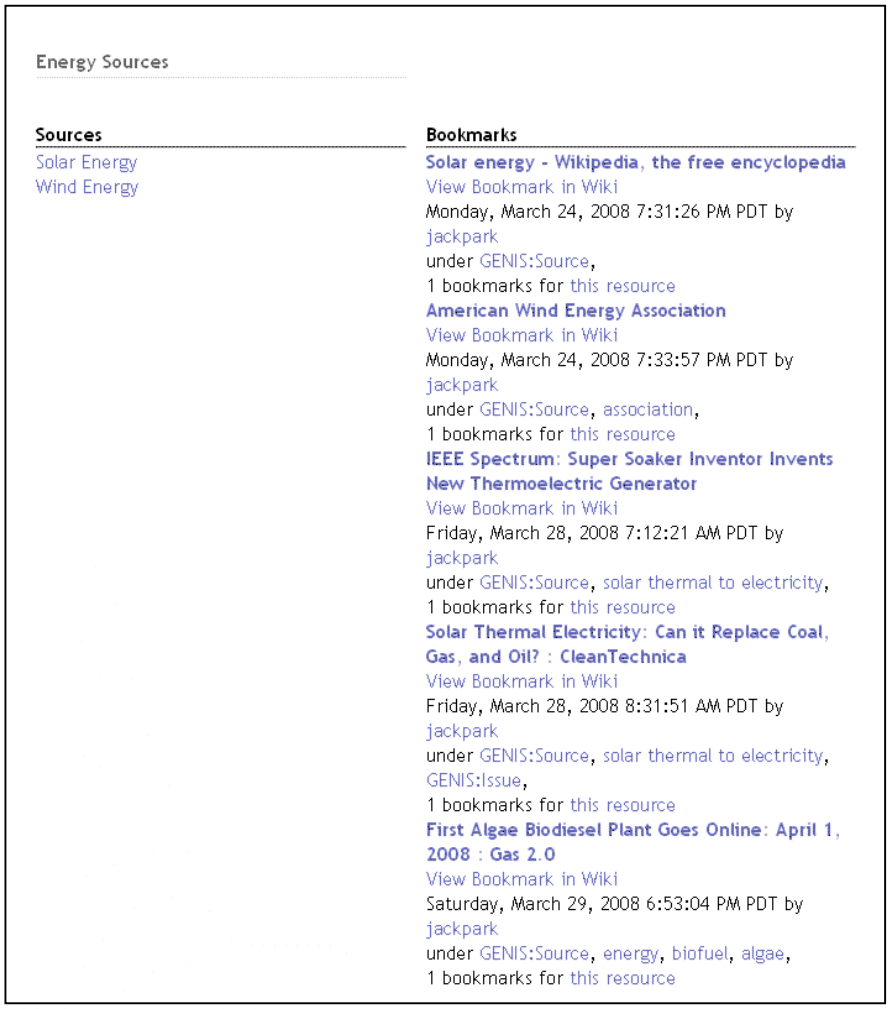

Fig. 11. A sample portal with a bookmarks dashboard view

Figure 11 illustrates an early instance of a dashboard. This dashboard uses a REST query as follows:

```
/ws/tago/tag/html/GENIS:Source
```

where the tag `GENIS:Source` is drawn from a tag ontology that allows us to bookmark using tags related to energy sources, uses, and issues.

Figure 11 also illustrates a *context view portal* as included in Figure 7, where we have created a view that facilitates navigation into the world of *energy sources*. Users are able to create new source links, and are also given ready access to websites tagged for the general class. A Web page for the subject *Wind Energy* (source) might include a bookmark dashboard that is a composite query on `GENIS:Source +`

`WindPower`, which narrows the source bookmarks to those also tagged with the particular source type.

Through such tagging and annotating processes, we believe that it is possible for communities of practice to create and maintain a knowledge base that fully supports the community's gardening activities through maintenance of dashboards of various kinds. Our project remains *work in progress*; we continue to explore the boundaries of dashboard construction; we have only now begun to scratch the surface of that inquiry.

Let us consider an instance of *connecting dots*. The semantic linking capabilities of Cohere allow us to read two different stories and lift out of them the following two *ideas*:

- Immune responses use Free Radicals to defeat bacterial infections
- Antioxidant supplements reduce Free Radicals from the body

Suppose now that we happened to tag each page with the tag "freeradical molecules". Allow that different individuals used the same tag and lifted those ideas independently.

Later, someone performs a tag-based search or discovers the tag "freeradical molecules" and notices those two ideas together. Those two ideas, to astute viewers, pose a problem: if you need freeradical molecules to fight bacterial infections, you probably don't want to be taking high-dose antioxidants. That inference might be based on a simple, common-sense heuristic as follows:

```
If      Process X REQUIRES Substance A
AndIf   Process Y REDUCES Substance A
Then    Reduce or Eliminate Process Y
```

With that heuristic, we now are able to suggest a claim to the knowledge garden that the exposure to `AntiOxidant` is contraindicated when `Immune Response` to a bacterial infection is active, offering the discovered ideas as evidence, as illustrated in Figure 12.

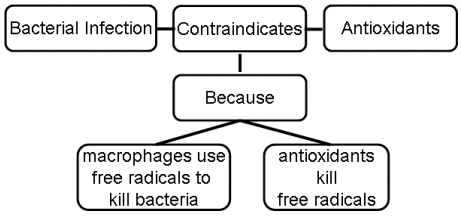

Fig. 12. An immune response discovery

How does our federation platform facilitate this discovery? TopicSpaces provides a social bookmarking tool, Tagomizer, along with the subject map that maintains the federated knowledge artifacts. Cohere can be accessed through Web services, with which a gardener lifts ideas out of Web pages visited perhaps at the same time the tagging process is engaged. The subject map keeps track of these actions, making them immediately available to those who follow on other journeys through the garden. We note that a similar federation platform can exist with other tools such as

http://del.icio.us/ providing the bookmarking capabilities. Our approach, by contrast, takes the federation itself as the starting point, building in the necessary tools and Web services.

In the broader context of knowledge gardening, one might ask "how were those *dots* found in the first place?" How does our knowledge garden platform support query? Support is found along two dimensions: full text search and navigation through social bookmarks (tags). Consider the tagging scenario where a gardener discovers the Web page from which the idea of Figure 12 is lifted. At the same time, that gardener tags the site with `ImmuneResponse` and `FreeRadical`. Another gardener discovers the Web page from which the idea of Figure 13 is lifted. That site is tagged with `AntiOxidant` and `FreeRadical`. Tagging behaviors such as just illustrated are suggestive of a *best practices* approach to tagging: freely tag with the major *terms* found in an information resource. Another gardener, for reasons perhaps related to a disease being researched, lands on the `FreeRadical` tag, observes two rather surprising ideas both related to the same subject, and reasons, as suggested by the heuristic, that, "if I am sick, perhaps I shouldn't be taking antioxidant supplements". For people fighting a disease that provokes an immune response that requires free radical molecules, the new discovery turns out to be an important one. Such is the nature of *Black Swan Events* [25]. The discovery of important concepts and ideas is frequently difficult to predict; organization of information in ways that facilitate *finding and connecting dots* turns out to be a valuable contribution to the efforts of collective actions to solve complex and urgent problems. Any form of federation of human knowledge is valuable. We have argued that subject-centric federation, as illustrated by our knowledge gardening platform, is an appropriate and useful approach to that federation.

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