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Boundary Infrastructures for IBIS Federation:
Design Rationale, Implementation, and Evaluation

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The Open University

Boundary Infrastructures for IBIS Federation: Design Rationale, Implementation, and Evaluation

Thesis Proposal for KMI Doctoral Program
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Boundary Infrastructures for IBIS Federation: Design Rationale, Implementation, and Evaluation

Abstract

Climate change is a growing concern to humankind, since the dominant view argues for rapid, significant changes in human behavior to avert catastrophic consequences. This is a complex problem, known as a wicked problem. A productive way forward is through creative, critical dialogue. Such dialogue requires new kinds of socio-technical infrastructure. We offer a socio-technical infrastructure, described as a boundary infrastructure, based on improvements to existing and emerging Issue-based Information Systems (IBIS) conversation platforms. IBIS is an emerging *lingua franca* of structured discourse. We survey a rich field of literature related to ecologies for human-computer collaboration, conversation, communications theory, scientific discovery, knowledge representation and organization, and software development. Our goal is to facilitate the elicitation of numerous IBIS conversations, seeking a large variety of opinions, facts, and world views; our contribution lies in a process of federation of those IBIS conversations. Our work entails the fabrication of a prototype collective intelligence platform we call Bloomer. Bloomer includes an IBIS conversation federation component, and will be disseminated to several communities of practice, particularly those engaged in activities related to climate change.

1.0 Introduction

> "My advocacy is much more towards having more intelligent discussions, which is completely naive and stupid and I realize that."
>
> —Gavin Schmidt (2009), Climatologist

Stephen Denning's Springboard stories (Denning, 2001) are short stories that set a tone, introduce a concept, and have the capacity to create a memorable context in which problems can be solved, larger stories told, and more. We offer a springboard story that introduces our research:

> In a recent conversation among people in the Silicon Valley, Steven Chu's idea of painting roofs white (Johnson, 2009) as a means to reduce carbon associated with building cooling was the subject. Imagine hundreds or thousands of such conversations occurring around the planet, some among scientists engaged in detailed deliberations. Further, imagine that these conversations can be gathered together, organized, and then presented as a unified view of an aggregate of world views on aspects of climate change. Some of those conversations occur among members of different communities, some originate as small conversations, possibly leading to a bright idea that might turn out to

be game changing; such ideas need to penetrate the borders of silos.

Established methods of conducting conversations through hypermedia means such as email, online forums, and chat rooms give rise to a greater number of people engaged in conversation than cultures have experienced before. This increased communication is, at once, a blessing, and a problem. The blessing comes from greater diversity of opinions and world views being expressed; the problem arises through poor conversational skills on the part of many participants. As we shall see, our solution is to approach the need for broad diversity of conversational contributions through facilitation of elicitation of world-wide *structured conversations* centered around issues that matter to all stakeholders, then combining those conversations by a process we all *federation* such that redundancy is reduced or eliminated and all aspects of the collected conversations are well organized according to the subjects covered; the conversations are rendered more navigable, more useful for further deliberations or other activities. We introduce the emerging *lingua franca* of structured discourse, Issue-based Information Systems (IBIS) (Rittel & Webber, 1973; Conklin et al., 2003; Conklin, 2005) as the platform for conversation elicitation; we introduce a topic map framework (ISO, 1999; Park & Hunting, 2003) to perform the federation process and organize all conversations around the many subjects covered.

We present another springboard story to illustrate the problem. Our story is from recent climate-change-related news items, known now as *climategate*, for which we are indebted to Wikipedia (2009f) for a *disputed* and documented summary of the situation (citations removed):

> "The Climatic Research Unit e-mail hacking incident, also known as "Climategate",[] began in November 2009 with the hacking of a server used by the Climatic Research Unit (CRU) of the University of East Anglia (UEA) in Norwich. Unknown persons stole and anonymously disseminated thousands of e-mails and other documents made over the course of 13 years.[] The university confirmed that "data, including personal information about individuals, appears to have been illegally taken from the university and elements published selectively on a number of websites."[] and expressed concern "that personal information about individuals may have been compromised."[] [..] Controversy arose after various allegations were made including that climate scientists colluded[] to withhold scientific information,[] interfered with the peer-review process to prevent dissenting scientific papers from being published,[] deleted e-mails and raw data to prevent data being revealed under the Freedom of Information Act,[] and manipulated data to make the case for global warming appear stronger than it is.[] "

The particular Wikipedia page for that story[1] is locked from editing and says this in a text box at the top of the page:

[1] Wikipedia climategate: http://en.wikipedia.org/wiki/Climategate_scandal

"This page is currently protected from editing until disputes have been resolved."

The page further explains the lock with this message:

"The neutrality of this article is disputed."

We present an example of poor communication skills. (Ram, 2009), commented following (Harkinson, 2009) online:

> "Oh yeah, bogus. Unlike the doctored climate data? Get a LIFE! anyways thanks for giving this useful information..."

The article (Harkinson, 2009) attempts to dispel an assertion made by a Russian entity that their climate data was subject to the manipulations claimed in the climategate scandal. The assertion is made more complex since it was made on a popular political television program.

An assumption in our thesis is that the established methods of hypermedia discourse mentioned provide insufficient structure with which to mitigate dysfunctional deliberations. Our research shows that it is possible to create a socio-technical framework which supports an *ecosystem* that facilitates more-thoughtful contributions to conversations necessary to deal with global issues that matter.

We will provide a technological contribution in the form of an open source Web-based collaboration platform we call Bloomer. Users will engage with it at online installations; it is composed primarily of an instance of MediaWiki, the core platform on which Wikipedia is built, coupled with extensions that allow a user to start or participate in structured conversations. Like Wikipedia, each Web page is a particular topic; each question, answer, or argument in a structured conversation is presented similarly as a topic. Planned interface designs will include applets or other views that present an entire conversation in a single graphical view (cf. Figure 1 below).

Our thesis is that we can show that the Climatologist Gavin Schmidt's (2009) advocacy for more intelligent discussion is neither naïve nor stupid, if one of the obstacles to realizing this is a suitable socio-technical infrastructure.

1.1 A Research Context

We selected the field of climate change of a focus of our research and experiments. As the climategate story suggests, climate change is, indeed, an issue that matters, so much so that conversations around that topic are not only heavily disputed, but disputed in such ways as to require severe interventions such as locking down the topic.

That Wikipedia topic lock and the nature of handling disputed issues provide an example of the need for improvements to socio-technical infrastructures for large-scale understanding and sensemaking. Clay Shirky (2005) introduces another aspect of large-scale community issues needing resolution:

> "A persistent theme among people writing about the social aspects of weblogging is to note (and usually lament) the rise of an A-list, a small set of webloggers who account for a majority of the traffic in the weblog world. This complaint follows a common pattern we've seen with MUDs, BBSes, and online communities like Echo and the WELL. A new social system starts, and seems delightfully free of the elitism and cliquishness of the existing systems. Then, as the new system grows, problems of scale set in. Not everyone can participate in every conversation. Not everyone gets to be heard. Some core group seems more connected than the rest of us, and so on."

Issues of social behavior in contested areas and the ability to participate at all create a need to federate widely-spread and diverse structured conversations. Federation, in our context, is simply based on a root dictionary definition: a process that *brings together without filters*. As a knowledge organizing process, federation organizes information resources by the subjects described in those resources, much as the index in the back of a book collects subjects and provides links to where those subjects are found in that book. A goal of the federation process is to help all stakeholders better understand the complexity of policy issues and to navigate the arguments, in the long run, without traversing redundant arguments. Let us be clear: this report will use the term *federation* in two distinct senses. One sense is as a *process* as just described, and the other sense is as *a collection of portals*, online meeting places where people conduct sensemaking activities, all wired together through the internet to a common knowledgebase where the prime federation process takes place.

Federation compares to the many website news feeds and their corresponding *feed reader* applications[2]. Federation, as we shall see, is a process not unlike that of aggregation performed by feed readers, where information items are collected together and then sorted according to dates, subjects, or authors. Our process adds notions of reduced redundancy and pre-organization of all resources according to the topics entailed in the resources. Our process thus adds benefits to existing practices, which serves our immediate discourse needs and which can be added to those practices later.

Let us make two important distinctions. The first distinction is that our research is constrained to the *structured* world of Issue-based Information Systems (IBIS) conversations, where

[2] Feed Readers: http://blogspace.com/rss/readers is a list of many available feed readers

heterogeneity derives from syntactic and semantic aspects of those conversations—a term we use synonymously with *dialogue map* (Conklin, 2005) and *issue map* (Conklin, 2008a) and which can be thought to include the term *argument map* (Twardy, 2004). We define an IBIS conversation as a structured collection of questions, answers, and arguments all elicited in relation to a particular context; such a conversation can exist as the collected thoughts of an individual, those elicited from multiple individuals collaboratively creating an IBIS graph structure, or those created by an individual engaged in facilitating a group conversation.

The second distinction lies among different conversation types. Let us distinguish between *conversations that matter* (Brown & Isaacs, 2005) and general social conversations. Ann Jaloba (2009), speaking of conversations in online breast cancer forums, suggests that the *nature of interactions on such forums may suggest that the best model may be one where interaction is structured by topics and information and interaction is mediated through topical hierarchies*. She explained her findings:

> "I looked at how often, and for how long people posted on this forum. Then I looked at the subjects of their posts. What I found suggests that, at least with the disease of breast cancer, people coming online to deal with a diagnosis of a serious illness are looking for a very specific form of help and social contact, very different from the patterns of contact which characterise social network sites."

Since our investigation is *about* IBIS conversations in sensemaking, we will use instances of such conversations throughout this report; each is crafted using the Compendium[3] software tool for mapping IBIS structures.

[3] Compendium: http://compendium.open.ac.uk/

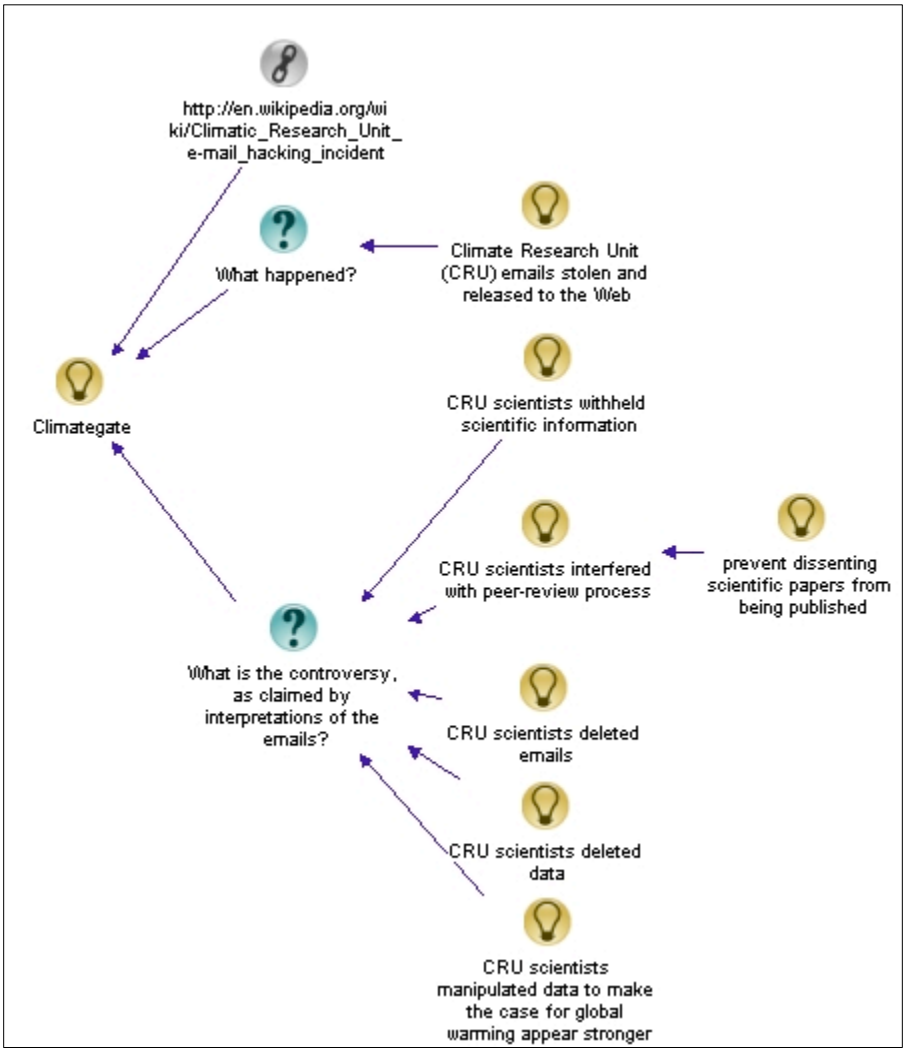

Figure 1 Climategate Based on Wikipedia (2009f)

Figure 1 is an issue map based on the climategate narrative presented above as found in Wikipedia. Figure 2, below provides a way to frame the controversial aspects of climate change, which lends some insight into why people care about climategate. Figure 2 results from a reflective analysis of Figure 1.

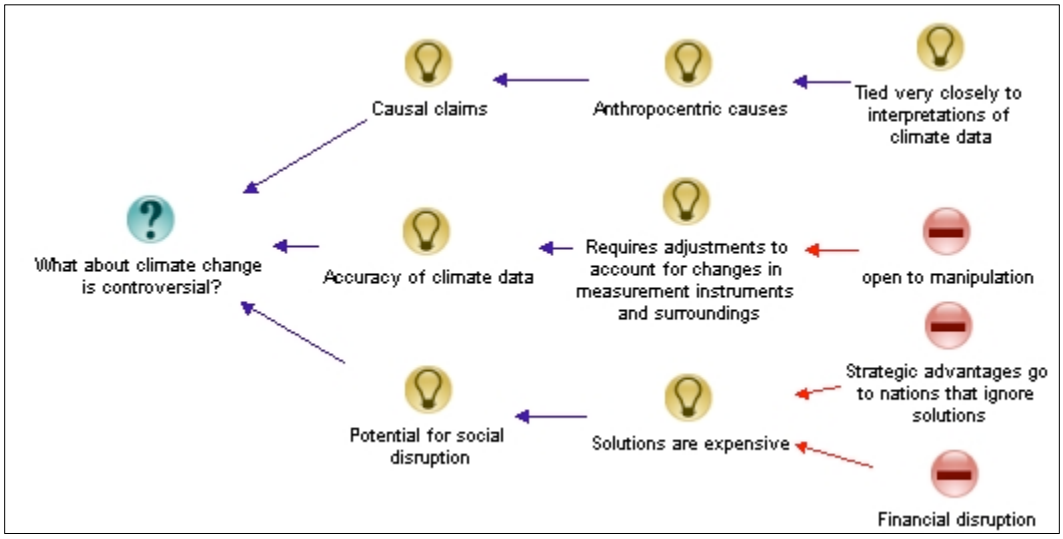

Figure 2: Nature of Climate Change Controversy

The claim that humans are causing climate change—the anthropocentric claim, specifically, global warming—arguably provides the most important venue for debate. But, to make any case for any source of climate change at all, we are forced to examine and interpret years of data for support. Thus, accuracy of climate data remains deeply related to any climate change claims made. This Wall Street Journal editorial opinion (WSJ-Opinion, 2009) commented on climategate:

> "The furor over these documents is not about tone, colloquialisms or whether climatologists are nice people. The real issue is what the messages say about the way the much-ballyhooed scientific consensus on global warming was arrived at, and how a single view of warming and its causes is being enforced. The impression left by the correspondence among Messrs. Mann and Jones and others is that the climate-tracking game has been rigged from the start."

Interwoven in the midst of claims and counterclaims is the social fabric of humanity, parts of which are comfortable with facing threats perceived to be important and willing to shoulder the burdens of solving related problems. Other members of society think in different time scales, tending towards dealing with immediate (e.g. financial) issues rather than long-term ones. Thus, we have the roots of a *wicked problem* (Rittel & Webber, 1973; Conklin, 2005). In the midst of this well-publicized controversy—indeed, the Wikipedia description of climategate remains in dispute as this is written—we derive research questions, the answers to which form the foundations of our research program and which, we believe, will augment human capability to rise above the controversy and find solutions. Our initial intuitions are animated by the notion

that the products of our research will provide insight into and possible improvements to the *ecosystem* that exists when human collaboration includes computer mediation.

1.2 Problem Statement

Sensemaking frequently entails decision making under uncertainty; some problems are wicked, meaning that the problems can be too complex to understand without dialogue, that different stakeholders will take different sides in debates (as is the case for climate change), or that frequently the right questions to ask in seeking solutions are not known *a priori* (§2.2.2.5). The controversies sketched in Figure 2 motivate the following applied problem statement:

> **Climate change is a growing concern to humankind, since the dominant view argues for rapid, significant changes in human behavior to avert catastrophic consequences.**Arguments on the basis of historical data that, when analyzed and extrapolated, suggest that a *tipping point* looms in a short time frame. To avoid that tipping point depends on changes in human behavior. There is however significant debate, ranging from the science of climate change, to the efficacy of different policies and courses of action.

This is a wicked problem.

> These debates, the way they are being conducted, and the wide range of literacy and scholarship exhibited combine to suggest that climate change is a wicked problem, one that creates large quantities of information resources with a great deal of heterogeneity in language, style, logic, structure and world views (beliefs) expressed

A productive way forward is through creative, critical dialogue.

> The experience with Wikipedia, as suggested by the fact that the climategate page (among others) is locked down until disputes can be settled, strongly suggests a failure of arguably otherwise successful approaches to the co-creation of knowledge artifacts on the Web. Settling disputes remains central to sensemaking; any way forward must include improvements to the facilitation of dialogue critical to contested issues.

Such dialogue requires new kinds of socio-technical infrastructure.

Central to our thesis as described below (§1.2) is the need for large-scale conversation that engages as many stakeholders as possible. By *large-scale* we specifically mean conversational contributions by many stakeholders; we do not mean one large conversation. Rather, we aim to support many conversations scattered widely. Those conversations need to be recorded, catalogued, indexed, and related to each other. We see many of these conversations being recorded face-to-face events that will eventually find their way into a public record, but, for the most part, we believe that the Web offers the best opportunity to conduct such conversations, recording, cataloguing, and indexing as the conversations occur.

1.3 Thesis Statement

It is possible to federate the heterogeneous artifacts of social discourse in a way that preserves their heterogeneous character while reducing the heterogeneity of their representations, and enables users to discover more information about subjects of interest after federation from other perspectives than prior to federation. Federation takes the form of a **map** that serves to maintain a **subject-centric** organization of all information resources represented in that map.

As we shall see, heterogeneity, by another name—*diversity*—is a valuable commodity. Our thesis restricts heterogeneity reduction to one particular aspect: the representation of federated artifacts to be served as views into an otherwise diverse population of ideas.

The origins of this thesis began with the author's collaboration with Steven Newcomb and the XTM authoring group to create an XML standard for topic maps. At that time, we produced the first book on topic mapping for the web *XML Topic Maps: Creating and Using Topic Maps for the Web* (Park & Hunting, 2003) by teaming with Sam Hunting to co-author and co-edit the work together with several other authors. Interest grew while employed as a research scientist at SRI International in the artificial intelligence labs, creating a software product for augmentation of human cognitive capabilities. Patrick Durusau and this author first described knowledge federation as defined here in a conference call to the ONTOLOG community[4] (Park & Durusau, 2006).

Climate change is already the subject of IBIS conversations:

- MIT's Climate Collaboratorium[5] (Malone et al., 2009)
- Debategraph's Copenhagen Summit Map[6]
- Open University's Cohere COP15 testbed[7]

As we shall see, this field is complex, and is thought, by many, to be urgent. That field will

[4] ONTOLOG Community: http://ontolog.cim3.net/
[5] Climate Collaboratorium: http://www.climatecollaboratorium.org/web/guest
[6] Copenhagen Summit Map: http://www.copenhagensummitmap.org
[7] Cohere COP15 testbed: http://globalsensemaking.wik.is/ESSENCE/Teams/COP15_ESSENCE_Team

give us ample opportunity to gain experience with the IBIS conversation platform we describe; our platform is slated to be installed in the Global Climate Change Situation Room in Gimcheon, South Korea as part of the Millennium Project's activities (Glenn, 2009) during the first half of 2010. It will also be installed for use in the ESSENCE[8] project at the Open University.

1.4 Research Questions

The Problem Statement introduced above concluded that *the provision of infrastructure for large scale, online discourse provides a plausible way to construct the collective intelligence needed to tackle wicked problems such as climate change*:

1. How do we create the right human-computer ecology for large scale, constructive debate? (§2.1)
2. What are the theoretical, technical, and social dimensions of that human-computer ecology? (§2.2)
3. What are the contributions of structure in conversations to the federation process? (§2.3)

Each of the research questions is now used to focus different literature reviews, to explore candidate design options, and to justify decisions. The answers to the questions thus provide the design rationale for our research platform.

1.5 Proposal Structure

The remainder of this proposal is organized as follows:

Chapter 2 surveys the literature in relation to the core concepts of our research: pattern languages and IBIS patterns, followed by studies related to each of our three research questions.

Chapter 3 follows our literature review and provides an illustrative scenario that illuminates the role of IBIS conversations in a larger sensemaking exercise.

Chapter 4 presents our contributions, as they are unfolding. These contributions entail the production of a prototype socio-technological infrastructure, plus related research exercises that engage software agents in IBIS conversation use cases and create a common IBIS document format for the exchange of conversations among different elicitation platforms.

Chapter 5 presents our research plan and expected timeline. The timeline anticipates a four-year effort to install Bloomer platforms, conduct field research while continuing the literature review of this rapidly expanding research topic, and to participate in conferences and write the final report.

[8] ESSENCE: E-Science/Sensemaking/Climate Change: http://events.kmi.open.ac.uk/essence

Chapter 6 addresses the risks associated with this research. Risks are identified as technical, social, and operational. Technical risks entail the ability of federation to function as expected, to add value to online discourse. Social risks entail the ability of participants to accept the new approach to structuring and conducting discourse mediated by a socio-technological infrastructure, and operational risks include those of completing the software project in a timely fashion.

Chapter 7 addresses ways in which this work can be evaluated. Evaluations include user feedback in the form of suggestion forms and direct feedback forms. Staged trials where users are asked to participate in specific conversations will be designed to evaluate the federation process.

Chapter 8 lists our references.

Appendix A presents a set of shell IBIS issue maps which have been created to explore the space of organizing climate change topics.

2.0 Literature Review

> "It used to be the case that there was a canon, a body of knowledge shared by all educated men and women. Now, we need the skills of a scout, the ability to learn, to follow a trail, to make sense out of faint clues, and to recognize the way forward through confused thickets. We need a sense of direction that carries us onward through the wood despite our twists and turns. We need "soft eyes" that take in everything we see, not just what we are looking for."
>
> –Tim O'Reilly (2009)

Throughout this report, we will frequently use the metaphor of a *lens*. A lens, as for instance, one found in reading glasses, magnifies or otherwise distorts light rays before they enter a human eye to be processed by the brain. As a metaphor, that concept allows us to play with the term *distort*. We imagine a particular lens through which a politically liberal individual would view events as different from a lens through which a politically conservative individual would view the very same events. We start with an issue map that portrays the context in which this research exists.

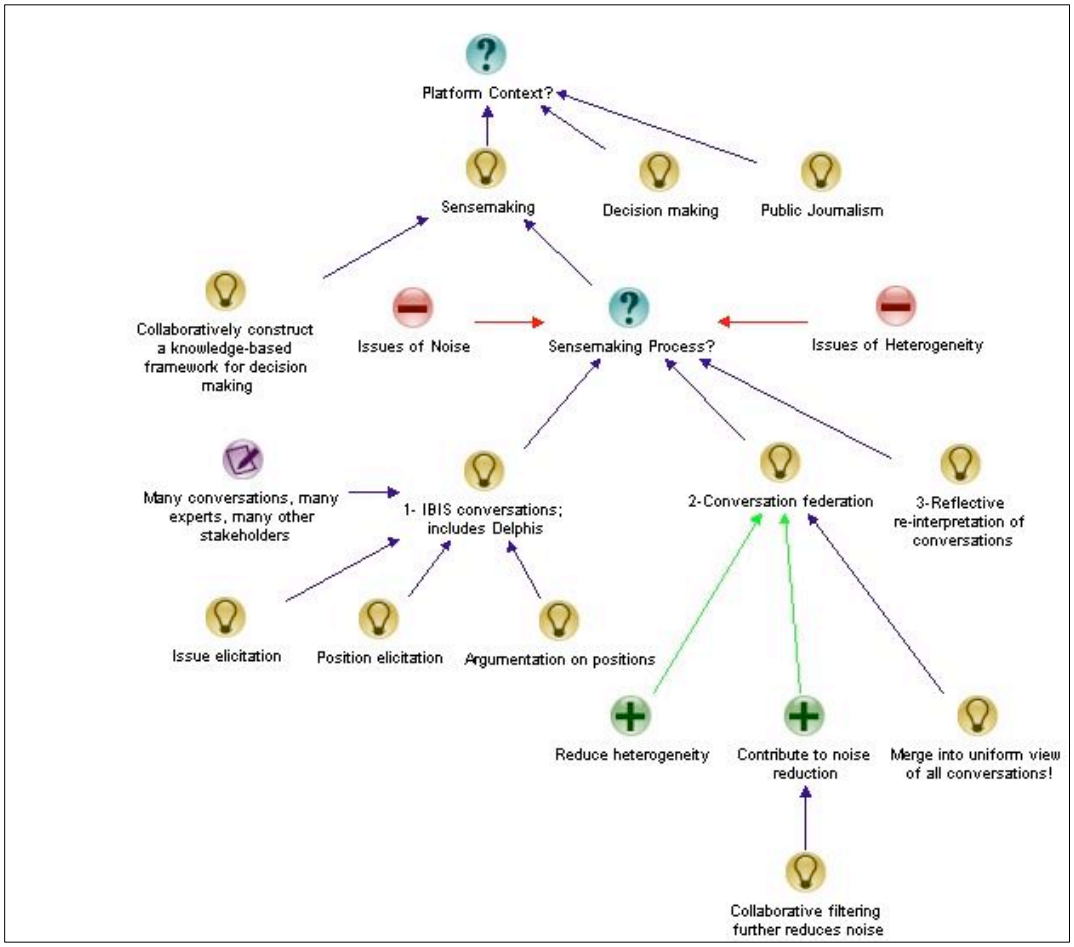

Figure 3: Overview of This Research

Our research is being conducted along the core dimensions of *action research*, *sensemaking practices, complex adaptive systems, social patterns and pattern languages,* and *software development patterns and practices.* As our research progresses, we notice an increasing tendency to examine the literature related to large-scale collaborative games.

As shown in Figure 3, we view sensemaking as a process that precedes decision making; in the context of IBIS conversations, we view three phases of the activity: elicitation of issues, positions and arguments, followed by conversation federation, and ending with reflective re-interpretation of the federated conversations.

One concept implicit in the fabric of this research is that of *Crowd Sourcing*, which is characterized as utilizing the *wisdom of crowds* (Catone, 2004; Surowiecki, 2004), outsourcing work to large crowds that can otherwise be performed internally, and the *application of Open Source principles to fields outside of software* (Howe, 2006, 2006a, and 2008). Crowd sourcing is another term for those activities found at Websites such as http://del.icio.us/, http://flickr.com/, http://slashdot.org/, http://wikipedia.org/ and others. Cass R. Sunstein (2006, p. 46), under the

heading "The Surprising Failure of Deliberating Groups", tells this cautionary story. He describes two groups, one liberal and one conservative, presented with a set of questions independently. Each group was asked for their responses to questions *prior* to meeting with the other group. The groups then met, deliberated on those issues, and then were asked the same questions again after meeting. At issue was a treaty to control global warming. While liberals were in favor of the treaty before deliberations, they were more strongly in favor of it after. While conservatives were neutral on the treaty before deliberations, they were strongly opposed to it after. Sunstein (2006, p. 47) says this:

> "Aside from increasing extremism, the experiment had an independent effect. It made both liberal groups and conservative groups significantly more homogeneous—and thus squelched diversity."

We do not know the circumstances under which the deliberations occurred, but we see that scenario as an interesting opportunity for consideration in experiment design. As we shall see, diversity of world views is a desired commodity.

As a prelude to the literature related to our research topic, we introduce two core concepts: *pattern languages* in general, and a particular pattern language known as *IBIS*. We introduce pattern languages and patterns with the belief that patterns entail expectations and those expectations will allow us to create a socio-technological infrastructure that exhibits anticipatory behavior (See (§2.3.4) for more) in understanding IBIS conversations, all for the purpose of supporting automated and socially-directed merge detection, a process we shall describe below (§2.2.2.4.1) and (§4.2.2).

Our research can be related to Christopher Alexander's *pattern languages* (Alexander, 1977). A pattern language is a named collection of patterns, captured in a formalized way such that they record the contexts in which a pattern exists, any other patterns entailed by a given pattern, and, among other things, how that pattern plays out. Nancy Glock-Grueneich (2003) says this about pattern languages in the context of her quest to find solutions to wicked problems through co-evolution of social systems and technologies:

> "We in turn are looking for social practices that may prove to be true patterns in the Alexandrian sense, patterns that can inform the design of social systems and of tools that coevolve to optimize collaboration and augment human effectiveness."

Pattern languages find their way into ecosystems comprised of communicating agents. Richard Gabrial and Ron Goldman (1998) created a pattern language for Sun Microsystems' JINI platform, which is an agent coordination system. The JINI pattern language was modeled on

a *chaord* which is the work of Dee Hock, creator of the pattern language that found its expression in Visa International. Dee Hock (1995) describes a chaord:

> "By Chaord, I mean any self–organizing, adaptive, non-linear, complex system, whether physical, biological, or social, the behaviour of which exhibits characteristics of both order and chaos or, loosely translated to business terminology, cooperation and competition."

The term "chaos" relates to a direction our research probes, that of complex adaptive systems. Whether a chaord lies in the future of knowledge federation remains to be seen, but the coordination of communicating agents will remain important. IBIS fits into the grand scheme of coordinating agents, people in this case—though we shall report on a brief excursion into using software agents to couple IBIS platforms (§4.3.2).

A brief chronological garden path leading to this research using Compendium and Compendium-like tools begins with Horst Rittel's introduction of wicked problems and IBIS (Rittel & Webber, 1973), leading to an IBIS realization in gIBIS (Conklin & Begeman (1988), and then to experiences with QuestMap, Mifflin and finally Compendium (Conklin et al., 2003). Parallel chronological paths emerge following Stephen Toulmin's *The Uses of Argument* (1958). Argument mapping (Hoffmann, 2007; Twardy, 2004; van Gelder, 2002) and Information mapping (Horn, 1989, 2003), among others, emerge to join forces in providing hypermedia means of structuring conversations.

Below (§2.2.1.1), we introduce the MIT Collaboratorium (Klein & Iandoli, 2008), which presents early evidence of trials using an argument map platform in medium-scale climate change deliberations. In their paper, they argue that the platform *offers the promise of enabling qualitatively more productive large-scale collaborative deliberations*. They suggest that their initial results appear to support that claim. Having introduced our core concepts, we turn now to the research questions. The MIT Collaboratorium is a predecessor to the MIT Climate Collaboratorium (Malone & Klein, 2007; Malone et al., 2009; Laubacher et al, 2009) which extends the basic dialogue features to include climate modeling and articulate plans of action (See Figure 9 below).

We view IBIS as a pattern language. It has a vocabulary, an ontology that describes its nouns and verbs, and a limited set of axioms, rules for use of those nouns and verbs. The particular subset of the IBIS vocabulary of interest to us is based on our Common IBIS Document Type project described below (§4.3.1), which entails the following vocabulary of *node types*:

- Map—a node that serves as a container for a conversation which is a collection of any combination of node types
- Question (synonym: Issue)—a node for posing issues which demand answers or questions that seek to refine or clarify the original question
- Answer (synonym: Position)—a node where claims (positions) are made, answers are given. Answers are ideas. An Answer node, can serve as the beginning of a conversation since it can be used to describe a situation that raises many possible issues. Answers demand responses that seek to either refine an answer, to ask questions on that answer, or to offer pro or con arguments.
- Pro Argument—a node that supports an answer
- Con Argument—a node that seeks to refute an answer

An IBIS conversation is a graph, a collection of nodes and arcs that connect them. Arcs represent the verbs, such as *respondsTo*, while nodes represent the nouns which represent the type of node. Each node is able to *contain* information resources; the two primary information resources are the statement uttered by the participant, such as "Carbon Dioxide is a greenhouse gas", and a space for expansion on the statement, called *details* in Compendium. In the details resource, a participant is has space to add whatever information, such as links, citations, or explanatory material as deemed necessary. We use that model of the IBIS platform throughout this research.

We turn now to our research questions. In the following sections, we examine a range of complex systems theory, drawn from a general field that includes chaos, evolution, and learning. We then expand into the nature of conversation; we apply a lens that seeks to view and discover aspects of storytelling. Then we approach the technical aspects of our socio-technological infrastructure and reveal a plan to use topic mapping as a core platform architecture.

2.1 How do we create the right human-computer ecology for large scale, constructive debate?

> "Reorganizing a complete university, or a complete department, or a complete faculty seemed premature and counterproductive. My experience with all this (personal and through the literature) brought me the idea that it is necessary to create a habit of interdisciplinary research as such in many different regions of scientific work. We must then bring these different research fragments together in continuous interaction with one another. For me it is not so important anymore to concentrate on an education effort, or on a level that takes care of the needs of administration or industry, but to

> concentrate on a kind of autonomous internal scientific interdisciplinarity of many small crystal seeds (if I may use this metaphor) that would qualitatively transform the overall environment." —Leo Apostel (Apostel & Vanlandschoot,1994)

> "The world looks different from the perspective of each person who beholds it. But when we dig down into the invisible memetic mycelium that connects people in a culture, we start to find deeper, shared worldviews, based on assumptions about the nature of life and reality that people espouse unthinkingly and often never question from birth to death. Dig down deeper still and we creep into the miraculous gossamer dimensions where psychology is not other than biology is not other than astronomy and the individual and the collective arise, inseparably, together, as two aspects of the same mystery. Perspectives all the way down." –Helen Titchen Beeth (Beeth, 2006)

We open this branch of our research by looking through a lens that inspects collective behaviors of living things like ants. We do so as we seek evidence of patterns germane to the design and fabrication of a socio-technological infrastructure. Through that lens, we see complex learning and adaptive behaviors at work, perhaps a *complex learning machine* in the words of Howard Blum (Blum, 2001). From his book *Global Brain* (Blum, 2001, page 42):

> "The result indicates that a collective learning machine achieves its feats by using five elements. This quintet of essentials includes: (1) conformity enforcers; (2) diversity generators; (3) inner-judges; (4) resource shifters; and (5) intergroup tournaments."

Bloom sees conformity enforcers preventing individual contributors from seeing the entire picture, as one imagines while watching ants in search of food; we see, instead, a need to facilitate each participant's seeing the largest possible picture as a means of surveying the landscape. An instance of conformity enforcement manifests in *partisan conformity*. Elizabeth Roodhouse (2009) studies the blogosphere related to the candidacy of Sarah Palin to conclude:

> "…the relationship between stridency and partisan conformity exposed by this paper illustrates a trend amongst conservative blogs to repeat the allegations of "liberal media bias often voiced by traditional conservative media outlets, contributing to an "echo chamber" effect in the blogosphere."

Diversity generators serve the purpose of stirring the pot in an evolutionary sense. We see the federation processes stirring pots from time to time as noticeably disagreeable assertions are federated with others. A necessary tension is thus the need for diversity as a means of seeking ideas and solutions, and a need for conformity to maintain control of the environment.

Inner judges reward the good stuff, sometimes ignore the bad stuff. We see a Reputation and Trust system (R&T) system as serving as an inner judge. Resource shifters, in the Bloom sense,

shift resources to support the important contributors. Perhaps we can say that our R&T facility plays a role, though shifting resources is not designed into our platform. As Bloom says (Bloom, 2001, page 167):

> "The hunger for attention and influence is far more primal than most realize...the most potent of the resource shifter's prizes isn't money; its influence, the joystick moving the collective eyes."

Many open source projects, e.g. those of the Apache Foundation[9], are pioneering the use of a meritocracy as a means of determining who gets to do what in a project. Software developers begin by downloading source code, modifying it, and submitting their modifications back to other developers who are empowered to judge the quality of work submitted. Eventually, some developers are nominated to become committers, those trusted to commit changes to the project's source code. The concept of intergroup tournaments suggests potential applications for the platform we are creating—learning and sensemaking games.

Yrjö Engeström (2009) draws from a similar biological scenario and suggests a metaphor, that of fungus/plant-root associations known as mycorrhizae communities, with which to think about human-computer ecologies:

> "Learning in wildfire activities is learning by swarming that crosses boundaries and ties knots between actors. It is also learning by building mycorrhizae communities by means of cognitive trails and social bonds that make the terrains knowable and livable."

Engeström (2009) describes *wildfire activities* as, for instance, skateboarding and the Red Cross. Those two examples are suggestive of a definition based on coming together to solve problems. Three characteristics are enumerated in Engeström (2009) (italicized are direct quotes):

- Actors engage in social production *oriented toward an object*
- Swarming behaviors in the activity are *foundationally collective*
- *The new patterns of social production do not take shape in pure forms. They hybridize and seek symbioses with [] structures of mass production*

Engeström's *social production oriented to objects* is equivalent an IBIS conversation's *focus on particular topics,* as suggested above (Jaloba , 2009).

Swarm-like behavior, otherwise labeled *swarm intelligence* (Tarasewich & McMullen, 2002; Bonabeau & Meyer, 2001), characterized frequently in the literature as *ant colony behavior* (c.f. (Dorigo et al, 1996). Ant behavior entails the marking of trails, using scents (Chi et al., 2001) as a means of colony self-organization. Leaving trails supports a *follow-the-leader* approach to

[9] Apache Foundation: http://www.apache.org/

interaction (Axelrod & Cohen, 2000), an example of which is apprenticeships. Engeström (2008) describes that swarm-like activity as *knotworking* (Engeström, 2008, p 20):

> "In Knotworking, collaboration between the partners is of vital importance, yet it takes shape without rigid, predetermined rules or a fixed central authority."

Another view of knotworking, swarm intelligence, and wildfire activities is that of a *flash mob* in which crowds gather for a particular purpose as organized by texting and wireless internet (McGonigal, 2005), perform, and then disperse. Flash mobs follow from Howard Rheingold's *smart mobs* (2002), where texting and wireless internet also serve as the communications infrastructure.

We explore the computational science known as *complex adaptive systems* as covered below (§2.2.2.1; that research ties together the concepts introduced in this section.

2.2 What are the theoretical, technical, and social dimensions of that human-computer ecology?

As suggested in the climategate springboard story and supported by even the most cursory observations of events surrounding international handling of climate change issues, the social dimension dominates human activity. All three dimensions are inter-related in complex ways.

2.2.1 Social Dimension

> "Each discipline has a normative culture, largely defined by their reward system and traditions. If the goal of institutional repositories is to capture and preserve the scholarship of one's faculty, institutional repositories will need to address this cultural diversity."
>
> – (Davis and Connolly, 2007)

IBIS conversations, as we have seen, are a component of a larger social process, sensemaking, which means literally making sense of some situation (Weick, 95). Sensemaking means applying human-directed processes of organizing information resources related to a situation, finding the right questions to ask, and deriving a framework with which to conduct an inquiry. Sensemaking involves a variety of activities such as foraging, filtering, organizing, connecting, and identifying issues or taking positions or arguments in dialogues. We summarize aspects of the social dimension that relate to our research as follows:

- Discourse in high-value problem domains requires a multitude of conversations
    - Sparse resources are in play
    - False or inaccurate resources are in play
- Heterogeneity among conversations creates issues to be solved

    - Differences in elicitation tools
    - Differences in elicited world views
    - Differences in the expression (sentence structure, language) of those world views
- Signals can be defined as ideas, questions, or arguments that are useful to those seeking deeper understandings of complex situations. Noise is defined as ideas, questions, or arguments that contribute little or nothing to particular conversations
    - There is a need to maintain the highest possible signal to noise ratio in conversations

Similarly, *dysfunctions* such as low signal to noise ratios, poor argumentation, and balkanization are identified (Klein & Iandoli, 2008).

We view the social dimension as animated by issues of signal to noise ratio. Our choice is motivated largely by observations of poor conversation skills evidenced in the many public comment fields made available online associated with articles related to climate change; our choice was the (Ram, 2009; Harkinson, 2009) example presented above (§1.0); One interpretation suggests that the comment adds nothing to the conversation. It is an instance of *noise*. Not all contributions to conversations are necessarily noise even when they appear so; what is signal and what is noise is a complex issue in its own right.

2.2.1.1 Human Behavior

The quote above (Ram, 2009) is an illustration of human behavior in contested discourse. In fact, it is a tame example; others people have exhibited far less civil behaviors. As an aspect of the social dimension, human behaviors have driven the need for two classes of collaborative system design:

- Community rules of engagement, about which we site an example below.
- Reputation and Trust (R&T) metrics applied to all users based on their contributions; R&T is a topic that lies beyond the scope of this research, but remains crucial to long-term success of large-scale online deliberation socio-technical platforms.

Mark Klein and Luca Iandoli describe the MIT Collaboratorium, an argument map platform, in an experiment in which 208 students were engaged in large-scale argumentation related to climate change. Their hypothesis is that the use of argumentation systems that provide systematic knowledge organization that provides a logic-based rather than time-based representation for capturing user contributions, coupled with evidence-based reasoning and critical thinking, will

preserve the large-scale participation while qualitatively reducing the prevalence of dysfunctions (mentioned above). Rules are suggested in (Klein & Iandoli, 2008) as follows:

> "Users are expected to follow a set of simple guidelines to ensure the map is well-structured. Each post should represent a single issue, idea, or argument and should not replicate a point that has already been made elsewhere in the argument map. […] Changing a post in order to undermine someone else's point of view is forbidden: if one disagrees with an idea or argument, the user can capture this by creating *new* posts that present their alternative ideas or counter-arguments."

MIT's Collaboratorium implements many of the features specified in a topic mapping environment, and it provides a model for rules to be incorporated in an IBIS pattern language. Those rules set out to enforce a particular set of human behaviors arguably necessary for successful large-scale online deliberations.

It is human nature to use lenses, that is, to take positions based on world views. A lens helps shape those world views by providing, perhaps through the "distortion" effect, filters that preclude seeing events in different ways. Human nature leads some to self-assemble into groups that share the same world views, balkanization, which leads to re-enforced discourse related only to a subset of the issues in play (Klein & Iandoli, 2008). Our thesis is that such balkanization will occur in distributed conversations—people will congregate with like-minded others, but the net effects of balkanization will be reduced when narrow conversations are federated with other conversations, some narrow, some broad, which expand on the range of ideas captured.

In all of those conversations, some contributions will seem more like noise; others will be seen as genuine signals, messages or contributions which are useful. We turn now to look at the issue of signal to noise ratio.

2.2.1.2 Signals and Noise

> "This leads to maybe the final question that I think about, which is, "how do you increase the signal to noise ratio in communication about complex issues?" We battle with this on a small scale in our blogs comment threads. In unmoderated forums about climate change, it just devolves immediately into, "you're a Nazi, no you're a fascist," blah, blah, blah. Any semblance of an idea that you could actually talk about what aerosols do to the hydrological cycle without it devolving into name calling seems to be fantasy. It is very tiresome." —Gavin Schmidt (2009)

Large quantities of information come our way on a daily basis. We ask: where in all that information are the signals? Signal-to-Noise-Ratio is defined (Wikipedia, 2009b) as the ratio of the power or level of a desired signal to background or disturbing noise. Some noise is valuable

in odd ways, some not; as the climate scientist Gavin Schmidt points out (2009) *the problem is that the noise serves various people's purposes.*

Consider again the (Ram, 2009) quotation above. Among other things, it appears (to us) to serve two purposes; one is to signal general agreement with the "doctored climate data" hypothesis that one lens amplifies in the pilfered emails; another is to thank someone (Harkinson, 2009) in a crude way. It could be said that the comment served one individual's purpose, and perhaps, at a deeper level, it serves, as if a vote for the "doctored climate data" hypothesis. Thus, to all for whom that lens applies, the comment serves a purpose. To others, it is more likely seen as pure noise.

That analysis suggests a question: Is there another way to express agreement (or disagreement) with a particular world view, one that is more useful to the goal of continuing a conversation? We see a need for people to express their world views; we believe that community rules of engagement coupled with R&T metrics will serve to enhance an overall signal-to-noise ratio. In a complex adaptive ecosystem, would human participants learn to contribute stronger signals under the social pressures of R&T metrics? For now, we look more closely at world views and sources of heterogeneity in collaborative processes that serve to communicate those world views in service of sensemaking.

2.2.1.2.1 World Views

> "This is the difference between us Romans and the Etruscans: We believe that lightning is caused by clouds colliding, whereas they believe that clouds collide in order to create lightning. Since they attribute everything to gods, they are led to believe not that events have a meaning because they have happened, but that they happen in order to express a meaning."
>
> —Seneca (Roman Philosopher, first century C.E.)

Let us introduce a way of thinking about world views with another Springboard story:

> *Hugo* was walking along a sidewalk on one side of a street while *Ben* was walking along a sidewalk on the other side of the same street. *Hugo* looks around and notices there are no crosswalks; he wants to go to the other side of the street. *Hugo* yells to *Ben*: "How do I get to the other side of the street?" *Ben* looks around, thinks for a while, and says: "You're already on the other side of the street."

We all have different ways of looking at things. We adopt personal *world views*, essentially, the ways in which we identify the *things* and *relations* of our universes. A world view is a complex network of ideas and relations, where any assertion contributed to an IBIS conversation entails numerous related concepts, issues, and arguments. For instance, if a political party claims to be the "party of <fill in famous president>", then, formation of a world view around that party

entails an understanding of just what that famous president stood for, together with related entailments. Adoption of particular world views is a source of diversity, but in large numbers, by way of redundancy, it can become a genuine source of noise. In terms of patterns, the suggestion becomes one of *voting* for a position stated in a node in a conversation rather than repeating it, even if stated in a slightly different way.

2.2.1.2.1.1 Perceptions and Interpretation

"Were the eye not attuned to the Sun,
The Sun would never be seen by it." – GOETHE

Suppose that we cast the *perceptions and interpretation* issue as the *lens problem*. Norwood Russell Hanson (1958, p.3) says this:

> "Let us examine not how observation, facts and data are built up into general systems of physical explanation, but how these systems are built into our observations, and our appreciation of facts and data. Only this will make intelligible the disagreements about the interpretation of terms and symbols within quantum theory."

Hanson (1958, p. 5) then tells this story [emphasis in the original]:

> "Let us consider Johannes Kepler: imagine him on a hill watching the dawn. With him is Tycho Brahe. Kepler regarded the sun as fixed: it was the earth that moved. But Tycho followed Ptolemy and Aristotle in this much at least: the earth was fixed and all other celestial bodies moved around it. *Do Kepler and Tycho see the same thing in the east at dawn?*"

Buried in the barrage of information flying at us are ideas, concepts, and questions; we need to find them and see them for what they are, for what they mean to us. Metaphorically, we refer to those ideas, concepts, and questions as *dots*. Consider the recent *sub-prime mortgage lending* fiasco (Wikipedia, 2009), in which several really interesting dots, including *rising housing prices*, *adjustable rate mortgages*, *sub-prime loans*, and *unqualified buyers*, were all floating about together, with few people paying attention; at the very least, people in positions to make decisions related to the juxtapositions of those concepts were apparently not paying attention or willfully ignoring them. Those dots should have been connected. That they were not connected meant that massive stress would eventually be placed on global financial markets, which can frustrate efforts to deal with climate issues. The *dot not mentioned* is *financial climate change*. The lens used by real estate brokers and bankers alike appears to be that of *forever rising land prices*. Diane Gurman (2009) illustrates dots not connected in relation to judicial wrangling over copyright issues:

> "According to Lakoff's theories, the legislative and judicial wrangling over copyright law issues is exacerbated by the fact that the two sides, progressives favoring openness and conservatives wanting proprietary rights — are not speaking the same language. While strict father adherents have stated their case based on values — that is, the right to make a profit, allowing the free market to operate, and protecting ownership in intellectual property — those in the nurturant parent corner have virtually ignored their own values and instead tried to make strictly rational arguments based on facts and figures, e.g., skyrocketing journal prices, the wording of open access policies, and actual versus purported market effects. While conservatives have constructed a single, coherent narrative centered around content providers and their property, progressives have instead built "issue silos, isolating one copyright issue from another the political equivalent of the database silos found in academic library Web sites. […] All this is not to say that the progressives' arguments aren't justified, but rather that they aren't being made effectively. The dots are there, but they aren't being connected."

Perceptions and interpretations are the *stuff* of world views. If one never experienced a decline in land prices, then one might not project one, even by analogy from other declining price events. But, if one had experienced that, as did the entire world during the *great depression* of the early 1900s, then one should be expected to at least have considered the possibility. Indeed, Alan Greenspan publically did so (1996) when he asked this question:

> "But how do we know when irrational exuberance has unduly escalated asset values, which then become subject to unexpected and prolonged contractions as they have in Japan over the past decade?"

Perhaps there is another *mechanism* at play. If we assume that people in positions of importance were aware of the *dot not mentioned*, then, given that no preventive action was taken by anyone to preclude the eventual financial meltdown of the first decade of the new century, perhaps people in important positions were not paying attention. Another view is that there were too many conflicting lenses in play—lobbyists and other political institutions that have reasons (financial) for mounting arguments that either mask or ignore real issues, the *dot ignored*. As Eric Raymond famously commented (2001), *Many eyeballs tame complexity*. In large-scale conversations, ignored dots are less likely to occur.

Linguistic and cultural relativism is thought to be in play. Ludwig von Bertalanffy (1968, p. 235) had this to say:

> "Our perception is essentially determined by our specifically human, psychophysical organization. […] Linguistic and cultural categories in general will not change the potentialities of sensory experience. They will, however, change apperception, i.e., which features of experienced reality are focused and emphasized, and which are underplayed."

A suggestion taken from the Bertalanffy quote is that, while, say, lobbyists may have the opportunity to experience reality in the same ways as others, they may not generate the same perceptions. We view the heterogeneity found in world views as indications of conversation patterns necessary to facilitate detection of differences and resolution to coherence. Some distance between differing positions may be due to perceptions that can be revisited, thus reducing the difference or perhaps aligning world views. In other cases, there may be an agenda that drives world views, rendering those positions immutable. We anticipate opportunities to discover conversation patterns that probe positional immutability.

Regardless of the goals behind the arguments, world views abound in debates. We turn now to a study of the ways in which those world views are expressed. Our interest in the technicalities of the ways in which people assert claims or defend or refute them lies in our need to process those claims, which we call IBIS statements in this research.

2.2.1.2.2 Expression of World Views

The previous section talks about world views, beliefs, and semantics, about *what is expressed*. Expression of world views, this section, relates more to *how* those beliefs are expressed; syntax is another source of heterogeneity. Consider a single question as if made in separate IBIS conversations in four different ways:

- `How does carbon dioxide affect climate?`
- `How is climate affected by carbon dioxide?`
- `How 'affects(carbon dioxide, climate)'?`
- `How 'affectedBy(climate, carbon dioxide)'?`

In the first two questions, we used different sentence structures to ask the same question. In the last two, we introduced logic statements coupled with a chosen verb to ask the same question. The last two examples anticipate conversation below related to mixing *robots*, software agents as participants into IBIS conversations perhaps with other agents, or with humans.

How users assert their thoughts in an IBIS conversation affects our ability to automate the federation processes we propose; use cases based on those questions exemplify issues related to the design of a federation platform.

2.2.1.2.3 Tool Heterogeneity

We introduce tool heterogeneity in the social dimension since user interfaces must respond to social habits and expectations. Tools that provide elicitation facilities for IBIS conversations

come in a wide variety of types, styles, and implementations. Our focus is on three particular platforms:

- Compendium
- Debategraph
- Deliberatorium

Each of those tools facilitates elicitation of IBIS conversations closely related to the underlying data model of Compendium. Each serves to elicit nodes as we described above (§2.0). Each supports a slightly different mix of other node types, and each supports different ways of opening an IBIS conversation. For instance, while Compendium appears agnostic on whether a conversation opens with a question or an answer node that serves to define a topic for conversation, Debategraph always opens with a *topic* node that defines a context for the conversation. That topic serves to elicit multiple questions (issues).

At the user interface level, each node has an equivalent text field into which a short statement can be made, for instance "`CO2 is a greenhouse gas`". Compendium's text field is virtually unlimited in the number of characters available to use; Debategraph restricts that field to 70 characters, while the Deliberatorium restricts it to 100 characters.

2.2.2 Theoretical Dimension

"Experience of life has taught me that the only thing that is really desirable without a reason for being so is to render ideas and things reasonable."

–C.S. Peirce, Science 20 April 1900

Ecology:

1–a branch of science concerned with the interrelationship of organisms and their environments

2–the totality or pattern of relations between organisms and their environment

–Merriam-Webster Online

Human-Computer Ecologies names a subject comprised of theoretical aspects of human behavior, computational augmentation of human cognitive capabilities, and human-computer interfaces. We frame this research as if human-computer ecosystems exist *within* a larger context driven by human existence in a much larger ecosystem. It is the relationship between humans and their environment, climate change being an instance of such relationships, which propels investigations into niche activities with computers seeking solutions to issues related to those outer relationships. A spectrum of different issues arises out of relationships that emerge in the niche formed by human communities that collaboratively mediate their research and deliberations with boundary infrastructures and boundary objects.

In this section, we seek to create a framework with which to evaluate an ecosystem that is comprised of humans and computational boundary structures. In a niche (habitat) formed by humans collectively sensemaking using computer mediation, the organisms are the humans, and their environment, in that niche, is the boundary infrastructure. Our framework will emerge from biological metaphors and the science of complex adaptive systems. We address that framework in the following sections.

2.2.2.1 Ecology

> "A human being is part of a whole, called by us the "Universe," a part limited in time and space. He experiences himself, his thoughts and feelings, as something separated from the rest—a kind of optical delusion of his consciousness. This delusion is a kind of prison for us, restricting us to our personal desires and to affection for a few persons nearest us. Our task must be to free ourselves from this prison by widening our circles of compassion to embrace all living creatures and the whole of nature in its beauty." – Albert Einstein, What I Believe, 1930

> "Just as the genes of organisms are competing for survival via the organisms they govern, so too are the universes of discourse of communities competing via the communities they govern."
>
> —Steven R. Newcomb (Newcomb, 2006)

The concept of food webs and associated vocabularies come to mind when thinking of the biological metaphor suggested by Engeström (2009). That vocabulary entails terms like niche, predator, prey, producer, consumer, parasite, and pathogen (Polisand & Strong, 1996). Engeström's mycorrhizal communities suggest another term: symbiotic association, in this case between fungi and roots. The metaphor is useful, but we must find a way to fold it into architecture for human-computer ecologies. By declaring the goal of such an ecosystem is to learn from each other and to make sense of complex issues, we discover a well-documented and very active research field, complex adaptive systems, with allied inquiry into artificial life, swarm behavior, cognitive science, and related fields.

We follow the conceptual outline expressed by John Holland (1995) for complex adaptive systems (CAS). A CAS must possess the ability to represent a requisite variety of information resources necessary to adapt. W. Ross Ashby (1958) introduced the term *requisite variety* to the domain of control systems and cybernetics to suggest that, for a control system to be able to maintain stability, it must be capable of representing at *least* as many states as the system it is controlling. We can link requisite variety to our need to collect and federate many conversations focused on issues that matter. Karl Weik (1995, p. 89) provides an interpretation that *human thought and action must be highly varied to grasp the variations in the ongoing flow of events*.

Weik then argues that a complex sensing system is required to capture a complex situation; a rich language is similarly required.

As we view the term CAS, we use it in the sense that we intend to create an architecture that serves as a socio-technological infrastructuer that facilitates complex, adaptive behaviors among the participants.

Holland enumerates the elements of a complex adaptive system as follows:

1. Aggregation—two senses: simplification through categorization in terms of what things *are* and how they differ from each other; and categorization in terms of what things *do*. This element deals with properties of things in the system.
2. Tagging—a mechanism for categorization
3. Nonlinearity—a property of a system that can lead to behaviors of the unpredictable kind. Feedback is a mechanism that can introduce nonlinearity into a system.
4. Flows—a property of a system that relates to more than sequential processes ; that aspect relates to the sequence of steps we consider important to sensemaking: foraging→filtering→elicitation→evaluation→storytelling. Flows also relate to a *multiplying effect* (Holland, 1995, p. 25) where passing along some item, say, a reward, from node to node (user to user) where a fraction of that item stays at each node, has a multiplying effect when considered over the whole transaction. We will appeal to this concept when we discuss a *reward system*—reputation & trust—also suggested by Holland, the *Bucket Brigade*. Flows also relate to a *recycling effect* (Holland, 1995, p. 25), where items returned to a system after use releases resources for further use.
5. Diversity—a dynamic property of a system. Holland (1995, p. 27) talks about entities filling niches in ecosystems; if an entity is removed from an ecosystem, leaving a "hole", the system must adapt to the change. Some entities create new niches. Dynamic, nonlinear patterns emerge; as Holland (1995, p31) says: *it is difficult to evolve a single agent with the aggregate's capabilities*. We interpret that to mean that knowledge federation cannot be envisioned as a statically scoped platform; it must be adaptive, it must be capable of evolving to meet emerging needs of the communities it supports. Diversity is our chosen approach to providing requisite variety.
6. Internal models—Holland's context for internal models is adaptive agents. In our context, the agents are human sensemakers, though we do not rule out software agents playing valuable roles in a federation. Models, as Holland says (1995, p. 31) provide predictive or anticipatory capabilities.

7. Building blocks—Holland refers to building blocs as *mechanism* (1995, p. 34). He speaks to reusability of components humans decompose from complex scenes. He then speaks to recombination of those building blocks into new scenes. We take a different interpretation of the term *building blocks* and think of them, instead, as *properties* of our federation, mostly the information resources we assemble through foraging and elicitation exercises. Information resources are, in our vernacular, the stock in trade for sensemaking. Some resources we may find while others we may create.

Each of those elements exists or is planned to exist or be represented in some form in our project. They inform a type of architectural desiderata for a boundary infrastructure, about which we speak next.

2.2.2.2 Boundary Objects and Boundary Infrastructures

> "Boundary objects are those objects that both inhabit several communities of practice and satisfy the informational requirements of each of them."
>
> – (Bowker and Star, 1999, p.297)

> "Any working infrastructure serves multiple communities of practice simultaneously be these within a single organization or distributed across multiple organizations….Boundary infrastructures by and large do the work that is required to keep things moving along. Because they deal in regimes and networks of boundary objects (and not of unitary, well-defined objects), boundary infrastructures have sufficient play to allow for location variation together with sufficient consistent structure to allow for the full array of bureaucratic tools (forms, statistics, and so forth) to be applied." – (Bowker and Star, 1999, p.313)

Susan Leigh Star (1989) introduces *boundary objects* as *those objects that are plastic enough to be adaptable across multiple viewpoints, yet maintain continuity of identity*. She identifies a simple, extensible taxonomy of boundary objects based on four types: repositories, ideal types, terrain with coincident boundaries, and forms. This research applies boundary objects in each of those types to the enterprise of aggregation and validation of large quantities of data that includes world views, beliefs, opinions, facts, theories, laws, and measurements, all expressed in IBIS conversations. Collections of boundary objects form an infrastructure to serve the needs of multiple communities. Bowker and Star (1999) refer to such a collection as a *boundary infrastructure.* In this work, we focus on a narrow definition of a boundary infrastructure, that which will support the elicitation and federation of IBIS conversations.

Since we are federating the cognitive activities of many people, we now enter the domain of *distributed cognition*; traditionally, computing was about individuals sitting in front of single computers, focused on tasks involving only local information (Hollan et al, 2000, p. 174). We are

entering a relational arena where distributed cognition (Hutchins, 1991; Ackerman & Halverson, 2004) is at play, meaning *a process is not cognitive simply because it happens in a brain, nor is a process non-cognitive simply because it happens in the interactions among many brains* (Hollan et al., 2000, p. 175). (Ackerman & Halverson, 2004) suggest that distributed cognition should be considered in two lights, the first of which is that the process is much more than symbol manipulation. The second, a commitment, is to a *unit of analysis defined in relation to the complex phenomena being observed*. Their descriptive example suggests that the goal of a collective process provides a basis of analysis. They cite the *navigation in a harbor* processes described in *Cognition in the Wild* (Hutchins, 1995) as evidence; two phases, one collective where many are working together and one where an individual is standing watch, are both analyzed against the goal of navigating a warship in a harbor. The goal of navigating a warship in a harbor reminds of Engeström's (2009) actors engaging in social production oriented toward an object and hybridizing their patterns to suit the situation. Individuals participating in collective sensemaking each bring to the collective their individual ways of knowing and communicating. Star (1989) introduced *boundary objects* as mediators among actors in heterogeneous problem-solving situations. Boundary objects are things that can be put between members of teams and used as a focus of conversation (Boland & Tenkasi, 2001, p. 63).

For any boundary object to serve its purposes, each participant in the collaboration the boundary object serves must *own* the object; that is, each must be a participant willing and capable of using that object in ways it is intended to be used. If participants are willing to use the boundary object that is an IBIS conversation's presentation, to follow the conversation and make useful contributions to the conversation, then the structured conversation is serving its purposes.

Boundary objects are mediating objects. (Domingue et al., 2001) consider an *ontology* to be a mediating object for a community that creates and uses it. Tom Gruber (2004) suggests that *every ontology is a treaty—a social agreement among people with some common motive for sharing*. Perhaps boundary objects can be recursive in the sense that each such object is a gateway that leads to further mediation. Bowker and Star (1999, p. 313) point out that working infrastructures serve multiple communities of practice; to do so the infrastructures serve as *boundary infrastructures* to aggregate *stable regimes of boundary objects* to serve the needs of those communities. Compendium serves, in our view, the purposes of a boundary infrastructure, where each node type available to a Compendium dialogue map is a boundary object. We consider a subject map as an instance of a boundary infrastructure given that it aggregates

subject proxy objects, which we assert to be boundary objects. From Bowker and Star (1999, p.314):

> "What we gain with the concept of boundary infrastructure over the more traditional unitary vision of infrastructures is the explicit recognition of the differing constitution of information objects within the diverse communities of practice that share a given infrastructure."

A dialogue map serving as conversational memory is behaving as *repository boundary object* (Star, 1989). When combined with other tools of hypermedia discourse such as Cohere, the map is part of a *boundary infrastructure*. In that infrastructure, information objects originating from diverse sources are mapped into a uniform representation of the subjects described in those objects and maintained in a topic map repository.

2.2.2.3 Community Management

> "Among primates, the cohesion of groups is maintained by social grooming; the time devoted to social grooming is linearly related to group size among the Old World monkeys and apes. To maintain the stability of the large groups characteristic of humans by grooming alone would place intolerable demands on time budgets." – Robin Dunbar (Dunbar, 1993)

We open this section with a quote from the British anthropologist Robin Dunbar, who predicts an optimal group size for humans *of 147.8. Because the equation is log-transformed and we are extrapolating well beyond the range of neocortex ratios on which it is based, the 95% confidence limits around this prediction* [] *are moderately wide (100.2- 231.1)* (Dunbar, 1993). Our interests here range from participatory behaviors—understanding the ratios of lurkers to contributors, to achieving a requisite variety of world views.

Related to Clay Shirky's comment above (§1.1), early research on participation (Whittaker et al., 1998; Hill et al., 1992) led Jakob Nielson (Nielsen, 2006) to report a 90-9-1 ratio for participation:

> "Participation inequality is not necessarily unfair because "some users are more equal than others" to misquote Animal Farm. If lurkers want to contribute, they are usually allowed to do so.
>
> The problem is that the overall system is not representative of average Web users. On any given user-participation site, you almost always hear from the same 1% of users, who almost certainly differ from the 90% you never hear from."

Nielsen (2006) lists patterns appropriate to encouragement of participation:

- Make it easier to contribute
- Make participation a side effect—he cites the example of Amazon's book

recommendation system being a side effect—recommendations are made—of people actually buying books.

- Edit, don't create—he suggests offering templates (or forms) rather than asking users to create new layouts or constructs. Editing from templates or choosing tags from a list of existing tags reduces heterogeneity in terms of terminological choices and sentence structures.
- Reward participants—he cautions against over-rewarding and encouraging dominate behaviors.
- Promote quality contributors—this speaks to a Reputation and Trust metric that promotes quality contributions.

Dunbar's research was on monkeys which used social grooming as their primary behavioral modality. Humans use conversation. Perhaps the Dunbar number is merely a clue. World Cafés (§2.3.3.4) set tables for 4 to 5 people. A large body of literature on multi-player online role playing games (MMORGs), not reviewed yet in our reports, is already known to suggest the pattern of breaking down conversations into what the gamers call *guilds* typically of 50 or so participants, where millions of players are online at the same time. Jane McGonigal (2007) describes a massive *performance* game in which thousands of people were engaged in the physical environment finding clues, answering questions, and collaborating with cell phones and wireless internet. The game was played by posting geo-locations on the web, which ultimately turned out to be the locations of telephone booths. Players eventually figured that out, found and answered the phones, and performed tasks. A key to making this work with thousands of players was the dispersed nature of the locations. Café tables and distributed locations for interaction form a set of patterns with which to conduct large-scale online deliberations.

When people work together, they form *epistemic cultures*. Karen Cetina (Cetina, 1999) tells the stories of two different epistemic cultures. She contrasts a community of *particle physicists* with a community of *molecular biologists*. She is *interested not in the construction of knowledge but in the construction of machineries of knowledge construction* (Cetina, 1999, p. 3), which, to us, are boundary infrastructures. She says (Cetina, 1999, p. 3):

> *"*Magnifying this aspect of science—not its production of knowledge but its epistemic machinery—reveals the fragmentation of contemporary science; it displays different architectures of empirical approaches, specific constructions of the referent, particular ontologies of instruments, and different social machines. In other words, it brings out the diversity of epistemic cultures.*"*

At a very high level, she points out that particle physicists are constrained by the cost of their instruments, limited, typically, to just one large instrument, which they must all share. They tend to work in teams. She contrasts that with molecular biologists that tend to work alone, using relatively low cost instruments. Within that spectrum of epistemic cultural styles, there remains a consistent opportunity to apply the tools of structured discourse to issues that arise; the nature of discourse remains the same regardless of the tools and cultures that generate issues as topics of conversation.

2.2.2.4 Subject-Centric Knowledge Organization

> "A traditional source of problems, often found in traditional conceptual modelling approaches, is to try and produce THE description of a joint reality." –Aldo de Moor (de Moor, 2004)
>
> A map is a visual representation of an area—a symbolic depiction highlighting relations between elements of that space such as objects, regions, and themes. –Wikipedia (2009c)
>
> "the map is not the territory" –Alfred Korzybski, 1931

We speak of relationships. They exist between humans and their environment, humans and their tools, and between humans. A subtle relationship also exists between humans and their knowledge, ownership. Personal knowledge ownership is one of the tenets of constructivist research (Adams, 2007). Scaffolding for personal learning in our context is provided by a *map*. We propose the use of *maps*—knowledge cartography at work (Okada et al., 2008; Quaggiotto, 2008; Goczyla et al., 2005)—as a component in the technological aspect of our solution. Indeed, we already speak in terms of *dialogue, issue,* and *argument maps*.

A *map,* as we use the term, is of a collection of symbolic representations of a universe of discourse, symbolic representations of information resources *about* a variety of *subjects*. Subjects in our context include issues, positions, and arguments collected in IBIS conversations. IBIS conversations are collections of nodes in a graph. Each node has its own identity sufficient to render that node *addressable* (capable of being fetched from a database for viewing or editing). Each node is a subject in the sense that any node represents an assertion made by some participant in a conversation; it gains identity by way of its node type (is it a question, answer...), its author (who is talking?), its creation date, and its surroundings (exactly which other node it is a response to, argument for or against, etc.). The node gains further elements of identity based on what the participant actually asserts with that node. Consider our trivial IBIS node which asks: *Is climate change affected by carbon dioxide?* There are three subjects entailed in that question: *climate change*, *carbon dioxide*, and the fact that the question was asked in a particular context.

Adam Cheyer and this author described topic maps as appropriate to federation in (Park & Cheyer, 2005). The 2005 paper described a simple realization that occurred during the creation of a *semantic desktop* computer application *Cognitive Assistant that Learns and Organizes* (CALO); we discovered that CALO users, typically office personnel and department managers, were not familiar with the internal representations CALO used for items we know as email, calendars, and so forth. CALO employees an ontology of technical terms, many of which were not the same as those used by CALO users. There needed to be a means by which we could combine (federate) the terms used by CALO users with those required by CALO to guarantee *semantic interoperability* among CALO installations. The motivation behind our discovery is this: topic maps allow one to identify a particular subject, and give that subject as many different names as required to satisfy different users. This capability is facilitated by virtue of the fact that topic maps do not rely on *names for things* as subject identifiers, though names *can* play a role in identity under a variety of conditions.

Different installations of CALO cannot be expected to *know* the names given to objects by other users, so the controlled vocabulary provided by the standard ontology used in CALO installations provides for inter-communications among CALO installations, while user-supplied names for things facilitate individual users in their day-to-day use of the system. A topic map provides a boundary object serving both the CALO ontology community, and CALO users who are able to configure the map to suit individual needs.

We extend that line of reasoning to the entire enterprise that is collective sensemaking. We cannot anticipate what *names for things* different individuals will apply to their contributions, but we can facilitate ways to negotiate agreement on the subjects entailed in our gestures. Our answer to our own question is thus:

> Subject-centric federation facilitates ease of use of the subjects and their related resources by different users, each with different needs, world views, ways of knowing, and ways of naming and describing. Subject-centric federation provides a framework, a boundary infrastructure to support those different needs.

As Aldo de Moor points out in the selected quotation, restricting discourse to *the* lone description or answer is problematic. His paper *Patterns for the Pragmatic Web* (2005) makes the case for pragmatic solutions, which he illustrates in Figure 4 (de Moor, 2005, with permission). We cast our work at the level of *The Pragmatic Web* in Figure 4 where *meaning negotiation* takes place. The figure illustrates the traditional (to the Conceptual Graphs community) statement *The cat is on the mat.* We ask: *which cat? which mat?* And, we argue that

knowing *which* is as important as the other forms of knowing (what, when, where, why, how). As we will discuss here, *subject identity*, deciding if two resources are about the *same subject*, is a necessary condition for federation, indeed, for the pragmatic web to serve its purposes.

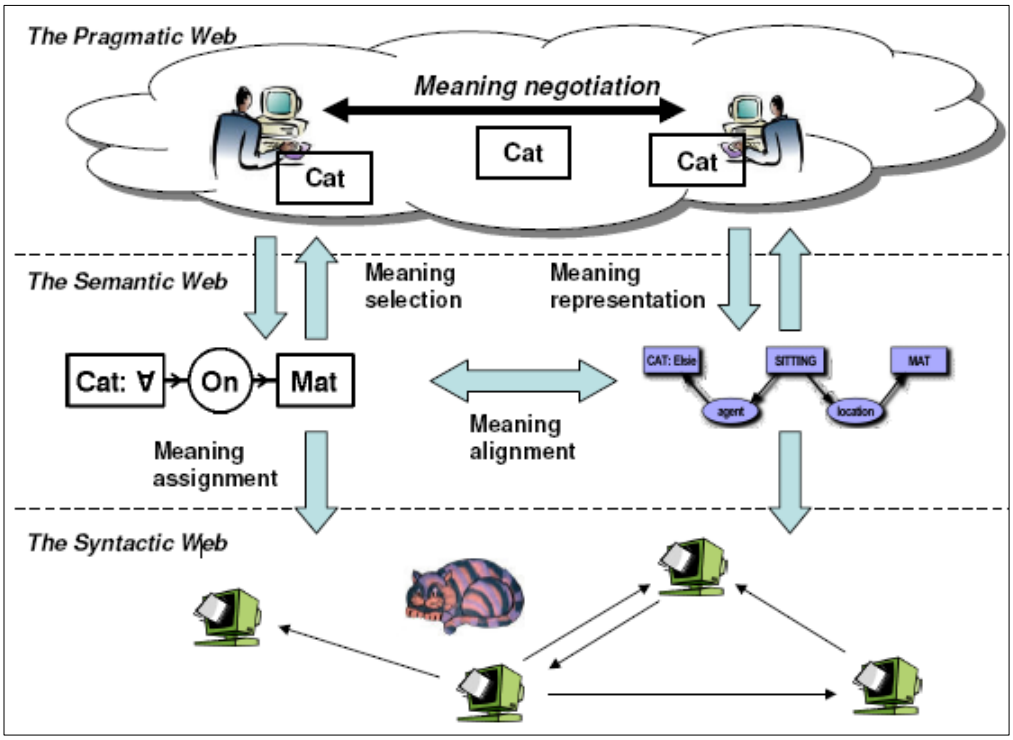

Figure 14: Conceptual Model of the Web

In the context of IBIS conversation federation, we are concerned with the subjects entailed in the assertions made in nodes. We are also concerned with the context in which those subjects are asserted. We hold this interest in the context of comparing different IBIS conversations to determine if they are *about* the same issue. We next define the term *Prime Context*, since that term represents the basis for conversation comparison.

Prime Context, in a simple IBIS conversation, is defined as an *opening issue (question)*, as for example the opening question illustrated in Figure 2 above. Not all IBIS conversations open with a question; some, as for example Figure 1 above, open with a *topic* node that invites multiple issues. Each of those is an instance, in our vocabulary, of a Prime Context. The decision to merge IBIS conversations is based on a comparison of their Prime Context nodes. In the context of meaning negotiation, we must be concerned that the entailed subjects are, indeed, the same in each case. As a trivial scenario where one of the subjects is a named entity, say, a person, then there is potential for ambiguity where many different people each are known by the same name. We shall return to that point below (§4.0) when be begin to outline the research steps we have taken and our solutions to such issues. To anticipate, we will introduce topic maps and

ontologies as systems that offer disambiguation capabilities in service of subject identification.

To introduce subject-centric knowledge organization, here is a sketch of how subjects are represented. We list a topic map-like structure that includes IBIS question and answer nodes and a subject associated with the name *carbon dioxide,* presented in a *frame-like* representation (described in more detail below (§2.3.4)):

```
Subject id="534"
      Names:           "gas"
Subject id="789"
      isA:             #534
      Names:           "greenhouse gas"
Subject id="456"
      Names:           "IBIS Answer Node"
Subject id="457"
      Names:           "IBIS Question Node"
Subject id="12345"
      Names:           "co2", "carbon dioxide"
      isA:             #789
      IBISQuestions:   #9879, ...
      IBISAnswers:     #9890, ...
      IBISPros:        ...
      IBISCons:        ...
Subject id="9879"
      isA:             #457
      Statement:       "How does co2 affect climate?"
Subject id="9890"
      isA:             #456
      Statement:       "carbon dioxide alters the balance of
      thermal radiation in the atmosphere"
```

The illustration anticipates an IBIS conversation re-represented as topic map subjects. To fully define the subject *carbon dioxide*, identified by its database identifier "12345", we needed to create representations for all the entailed subjects. Note that the IBIS nodes in question exist as subjects identified by "9879" and "9890". Using that structure, as might be fabricated and maintained by a topic map, we are able to create queries to support research, and to support on going IBIS conversations. We have more to say about that later.

The federation process itself lends to combinations of operations that are:

- Fully automated same-subject identification and merging
- Fully automated same-subject identification and *suggestion* that merging is appropriate, waiting for some predefined level of participant-derived approval before merging
- Participant-contributed *suggestion* that merging is appropriate, followed by merging
- Un-merging contested merged subjects

To introduce automated same-subject detection, we next describe a merging algorithm that

applies IF-THEN rules or other subject detection algorithms to the task.

2.2.2.4.1 A Merge Algorithm

An IBIS conversation merge, expressed in a pseudo-code form, looks like the following:

```
Given two root nodes to merge
        LOOP: if two nodes pass a same-subject test
                merge them into a new federated conversation
                Collect all child-nodes from each parent
                For each pair of child nodes, one from each
                collection
                        Branch to LOOP
```

The code is a depth-first iterative process that walks down an IBIS conversation tree based on two given IBIS conversations. The process will be described in more detail below (§4.2).

2.2.2.4.2 Topic Maps

Our research platform facilitates the fabrication, maintenance, and use of a *topic map* (Park & Hunting, 2002; ISO, 2005). A map serves as a collection of proxies that individually contain *representations* that describe a particular subject. Each map must fully *disclose* the ways with which it describes its subjects, and it must also disclose the rules required to compare subjects to support merging; the prime directive of topic mapping is *one proxy per subject*. Our project is based on the Topic Maps Reference Model (TMRM) (ISO, 2005, Part 5), which we interpret as a specification of a discipline. Thus, we see topic maps as less a technology and more a discipline. That discipline is brought to bear in federation of IBIS conversations. In particular, we are interested in the merging processes and the rules that guide merging decisions.

A topic map is a graph structure, as is a dialogue map, but with subtle differences. A topic map adds features to the *concept map* structure (Novak, 1998) that underlies Compendium and other dialogue/argument map platforms. Briefly, a topic map graph replaces the *nodes plus labeled arcs* structure of concept maps with *subject nodes plus relation nodes* structures. Labeled arcs in concept maps become subject nodes in the topic maps graph; relations are now subjects. This simple change enables the relations to serve as actors in other relations. We thus gain the ability to challenge a relation because it is addressable as a subject, a capability achievable in concept maps only when a particular labeled arc is reified as a node. For the most part, we end this section by reminding that the dialogue/argument map tools related to elicitation of IBIS conversations do not need the ability to challenge relations. That capability better serves purposes that arise during a reflection phase of sensemaking.

Topic maps serve the purposes of both boundary objects and boundary infrastructures, which we discuss next. A subject proxy, serving as a container for representations of a particular subject, grants access to all participants representations in any degree of granularity, language, or view specification necessary to serve the pragmatics of meaning negotiation.

2.2.2.5 Sensemaking Patterns—*Structuring the Unknown*[10]

> "It's at first difficult to see what technological paradigm follows from the community rather than delivery view of education. As each community has its own specific interests, its own ways of knowing, its own central endeavors, generalizing seems out of place. But communities are made up of people, and at the heart of all social relations and practice lies human communication of one form or another. On the basis of this assumption, we suggest that learning technology should be built around a conversational paradigm." – (Brown & Duguid, 1996, §9)

> "…sensemaking is best described as developing a set of ideas with explanatory possibilities, rather than a body of knowledge. This means that the topic exists in the form of an ongoing conversation…" – (Weik, 1995, p. ix)

> "The little girl had the making of a poet in her who, being told to be sure of her meaning before she spoke, said: 'How can I know what I think till I see what I say?'"
> –(Wallas, 1926, p. 106)

The roots of sensemaking lie in *Action Research.* Action Research is a problem-solving methodology based on inquiry into human problems in real contexts. It is fundamentally *field-based* compared to laboratory research exercises that use scientific methods related to hypothesis testing. Ann Curry (2005) reports that Kurt Lewin (Lewin et al, 1939), a social psychologist at University of Michigan, required that *any theories generated be fed back immediately into the research project—put into action*. By the late 1940s, action research was applied to social issues following World War II.

Curry (2005) enumerates the basic steps of action research as follows:

1. Observe the situation, define and describe the problem, its environment and context
2. All stakeholders (researchers and community) analyze and interpret the situation, including literature review

All stakeholders plan an action that will lead to problem resolution, carry out the action, and evaluate the results.

Karl Weik (1995, p 11) points out that *a crucial property of sensemaking is that human situations are progressively clarified, but this clarification often works in reverse*. In the same sense where Jeff Conklin points out in Chapter 1 of his book (Conklin, 2005) that, for wicked

[10]Structuring the Unknown: (Weik, 1995, p. 14)

problems, *you don't understand the problem until you have developed a solution*, Weik (1995) goes on to say: *It is less often the case that an outcome fulfills some prior definition of the situation, and more often the case that an outcome* develops *that prior definition*. Dave Snowden (2005) tells a story that illustrates this argument. He imagines organizing a birthday party for young children in which you prepare PowerPoint slides to articulate a mission statement, project plan, and so forth, giving clear milestones for the event, then asks if that is how you would handle what could be a chaotic situation. Snowden's answer:

> "No! Instead, like most parents, you would create barriers to prevent certain types of behaviour, you would use attractors (party games, a football, a videotape) to encourage the formation of beneficial largely self-organising identities; you would disrupt negative patterns early, to prevent the party becoming chaotic, or necessitating the draconian imposition of authority. At the end of the party you would know whether it had been a success, but you could not have defined (in other than the most general terms) what that success would look like in advance."

It is worth mentioning that Snowden's answer reveals numerous patterns that may prove useful in an emerging pattern language.

Klein, Moon, and Hoffman (2006) argue that it is a myth that *sensemaking is simply connecting the dots*. They argue that this myth ignores the skills necessary to identify the dots in the first place. We earlier spoke to the notion that dots have been there to see, but were apparently not seen by those in positions of authority to make the connections and behave according to what was learned. Our interest lies in those sensemaking behaviors and patterns that relate to the conduct of IBIS conversations. A hint can be derived from the Wallas (1926) quote *'How can I know what I think till I see what I say?'* Our interest in IBIS conversations is motivated by a belief that, through structured conversation, *dots* will emerge for discovery with opportunities to form connections either within the conversation or in later reflective review.

Sensemaking patterns associated with our inquiry relate to the application and appropriate use of classes of boundary objects. The classes of interest are these:

- Repository—to persist the collected gestures (use inputs) of conversation participants
- Forms—to facilitate elicitation of those gestures. We add that the graph structure of an IBIS conversation provides a standardized way to organize those gestures.
- Ideal—we identify the shared display of an IBIS conversation as a boundary object of the *ideal* type in the same sense that figures in papers capture information.

2.2.3 Technical Dimension

The technical dimension of our problem and solution spaces can be summarized in the following

requirements statements:

- Resolve heterogeneity by re-representation of information resources into a map that offers the following properties:
    - Maintain a subject-centric organization of all resources in the same way as an index at the back of a text book
        - At least one form of noise—multiple instances of the same resource—is reduced or eliminated when resources are collected into the map
- Facilitate collaboration processes which work with the map through participants following existing and emerging behavior patterns
    - Social and technical needs of collaboration are augmented when technology provides affordances for improved behavior patterns

We offer the following claim as an introduction to the nature of our research:

> A purpose of IBIS conversations is to provide a *sampling variety* sufficient to help identify signals in a noisy information environment.

A loose translation of that claim is that we want to capture a *requisite variety* of opinions, beliefs, and expert positions taken when seeking responses to issues raised in complex situations. We are thus narrowing our focus to one particular aspect of sensemaking through IBIS conversations: dealing with information overload through elicitation of issues, positions, and arguments related to some issue or context.

2.3 What are the contributions of structure in conversations to the federation process?

We begin by arguing that structures are defined by patterns. From that, we argue that patterns are being aggregated by *pattern languages*. We examine pattern languages first, and then examine a number of patterns that relate to this research.

2.3.1 Patterns within Pattern Languages

IBIS conversations are limited to a particular structure and semantics, one in which IBIS rules of engagement apply. An IBIS conversation begins with a prime context, either a *topic of discussion* which then invites multiple issues to arise, or a single issue (question) given typically in a much larger context (the *topic* just mentioned). Our intent is to base the envisioned pattern language on patterns that emerge from IBIS structure and semantics, and then extend it with patterns derived from external research and perhaps those that emerge during the conduct of our own research. We characterize patterns as follows:

- IBIS Pattern Language
    - Patterns from the IBIS Ontology: Nodes and their Relations
    - Conversational patterns that use those nodes and relations

The nature of those conversational patterns will emerge as our research continues. We next examine fragments of IBIS conversations.

These fragments illustrate just one aspect of conversation structure, that which is entailed by the IBIS conversational structure itself. In this illustration, we introduce the nature of federation as it is implemented in this research. Here is a trivial scenario to illustrate the subject-centric federation process. Consider two IBIS conversations as illustrated in Figure 5.

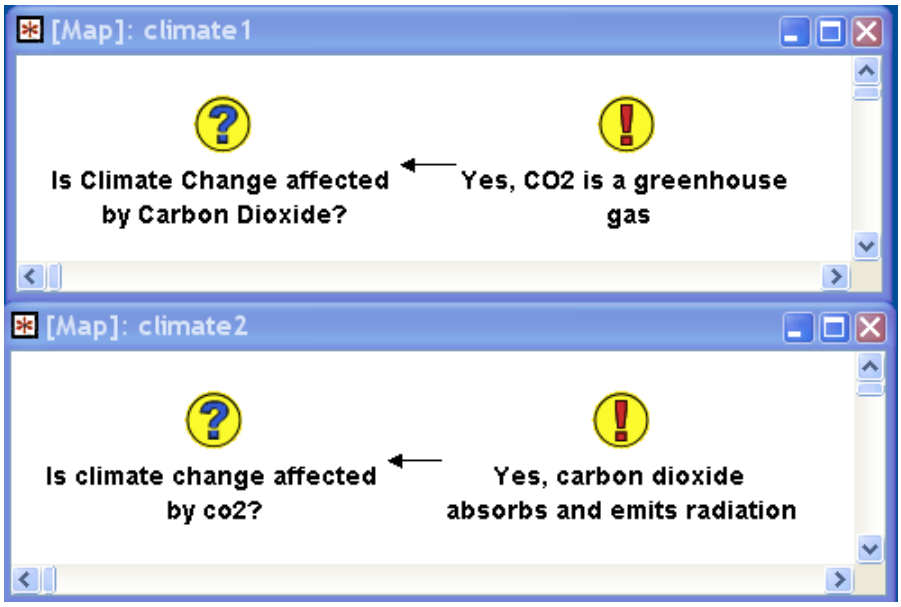

Figure 5: Two Separate IBIS Conversations

On inspection, humans recognize that *carbon dioxide* and *co2* are names for the same concept, a gas composed of one carbon atom bonded to two oxygen atoms. Humans recognize that both IBIS conversations are opening with the same question. Under conditions where it is deemed valuable to view all known IBIS conversations about the same issue together, then the merging process we describe below is invoked, leading to a single *federated* IBIS conversation as illustrated in Figure 6.

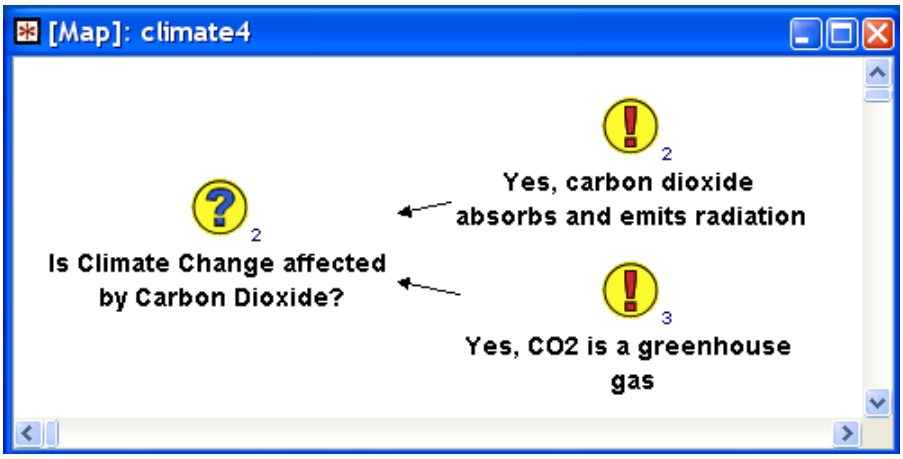

Figure 6: Merged (Federated) IBIS Conversations

2.3.2 Ontologies as Patterns

Niel Benn (2009) has explored a highly related topic in his thesis research, that of modeling scholarly debate. While he describes a larger ambition of *supporting more powerful analysis of the knowledge in the literature*, his quest remains closely related to ours of analyzing statements made in IBIS conversations. He describes interest in discovery of so-called *intellectual structures* in knowledge domains which are comprised of clusters of researchers and or publications together with the dominant topics in those domains. He identifies this technique as *Bibliometric* and cites (Andres, 2003). Benn then goes on to describe techniques of *conceptual modeling*, which leads directly to ontologies.

Continuing his reporting, Benn describes a hybrid ontology-based—graph-based method of detecting viewpoint clusters, about which he says:

> "However, [...] the cluster analysis cannot be directly applied to the semantic representations of the debate. Thus, a mechanism is needed that can translate the ontology-based semantic representation into a simplified form that is suitable for cluster analysis to be applied. This thesis proposes that such a mechanism can be implemented as ontological inference rules that are based on a theory of how people use a limited set of cognitively-based parameters to interpret more complex relations between units of information, thereby breaking new ground by spanning the research fields of knowledge representation and psycholinguistics in a new way, via the use of a cognitively-based vocabulary of coherence parameters for implementing the inference rules."

He employs a rule-based analytic technique that is not similar to our rule-based merging algorithms, so we have no direct comparison to make in relation to rule-based language processing. Still, ontologies bring structure and patterns to our processes. They offer support regardless of the direction our conversation analysis eventually takes.

2.3.3 Conversation

"If you have an apple and I have an apple and we exchange apples then you and I will still each have one apple. But if you have an idea and I have an idea and we exchange these ideas, then each of us will have two ideas." — George Bernard Shaw

"As workers shared tortilla and bean suppers, they also shared the *if-onlys* of their lives and imagined the impossible. With practice, they began to ask the *what-if* questions. And from the *what-ifs* came the *why-nots!*" —(Brown & Isaacs, 2005, p. 2)

"It is still my deepest belief that it is through conversations around questions that matter that powerful capacities for evolving caring community, collaborative learning, and committed action are engaged—at work, in communities, and at home."
—(Brown & Isaacs, 2005, p. 2)

"If an essential part of Web 2.0 is harnessing collective intelligence, turning the web into a kind of global brain, the blogosphere is the equivalent of constant mental chatter in the forebrain, the voice we hear in all of our heads. It may not reflect the deep structure of the brain, which is often unconscious, but is instead the equivalent of conscious thought." —(O'Reilly, 2005)

"Conversation is king. Content is just something to talk about." —Cory Doctorow

We use the term *conversation* throughout this report to frame our research in various conversation theories. An origin of the barriers to federation is found in these words from the Bible: *Come, let Us go down and there confuse their language, so that they will not understand one another's speech.* (Genesis, 11:7, King James Version); not only are there varieties of language, but within each there are communities of practice that create specialized vocabularies which further compound language barriers. We are creating a facility which captures human discourse *as is* that facilitates users finding information resources from various language groups while remaining within their own.

In this section, we review literature related to two specific theories of conversation, one articulated by the scientist David Bohm, and the second from the scientist Gordon Pask. Bohmian dialogues are, in our context, related more to the *practice* of IBIS conversations, while Gordon Pask's *conversation theory* articulates the nature of entailments associated with *speaker-listener* relationships in any conversation. We follow with descriptions of other classes of boundary infrastructure that support conversation: Delphis, World Cafés, and Kelly's Personal Construct Theory.

2.3.3.1 Bohmian Dialogues

"We can't solve problems by using the same kind of thinking we used when we created them."
—Albert Einstein

> "…it may be said that the two people are making something *in common*, i.e. creating something new together." —(Bohm, 1996, p. 3)
>
> "The way to start a dialogue group is usually by talking *about* the dialogue—talking it over, discussing why we're doing it, what it means, and so forth." —(Bohm, 1996, p. 6)
>
> "We each agree alike to think, but not to think alike." —Glen B. Haydon, M.D. (1982)[11]

David Bohm (1996) suggests that something new can be created only if people are listening to each other, without prejudice, and without trying to influence each other. He contrasts the word *dialogue* with the word *discussion*: dialogue, by virtue of its roots, suggests a *stream of meaning*, whereas discussion, by virtue of its roots, suggests breaking things up into analytical units or points of view. He says: *Discussion is almost like a ping-pong game, where people are batting ideas back and forth and the object of the game is to win or get points for yourself*. He further points out that in a dialogue, nobody is trying to win, that everybody wins if anybody wins.

A Bohmian dialogue is really about the thought process involved, about changing the thought process that occurs collectively. It is about engaging in thoughts, and paying attention to the thought processes, not the content of those thoughts. By way of illustration, he says: *The whole ecological problem is due to thought, because we have thought that the world is there for us to exploit, that it is infinite, and so no matter what we did, the pollution will all get dissolved away.* David Bohm informs this research in profound ways. From (Bohm, 1996, p. 16):

> "Now, you could say that our ordinary thought in society is incoherent—it is going in all sorts of directions, with thoughts conflicting and canceling each other out. But, if people were to think together in a coherent way, it would have tremendous power."
>
> "The tacit [that which is unspoken] process is common. It is shared. The sharing is not merely the explicit communication and the body language and all that, which are part of it, but there is also a deeper tacit process which is common. I think the whole human race knew this for a million years; and then in five thousand years of civilization, we have lost it, because our societies got too big to carry it out. But now we have to get it started again, because it has become urgent that we communicate. We have to share our consciousness and to be able to think together in order to do intelligently whatever is necessary."

Bohm suggests that, in a dialogue group, crucially, *we are not going to decide what to do about anything*. The goal is to maintain an "empty cup", to keep the dialogue free and open. A purpose for a Bohmian dialogue is to communicate freely and in truth. The process is

[11] Haydon Quote: That quotation was first heard from Dr. Haydon (1982), but it may well be due to an unknown prior author.

transformative in the sense that there is, first, a *negotiation* process that allows participants to say "OK. I see your point". Such transformation occurs when participants, who typically come into a dialogue with agendas and points of view learn to trust and appreciate the other participants such that an open mind is available for the dialogue itself. As a participant in a World Café session said (Brown & Isaacs, 2005. p. 81): *People often want to jump too quickly into action.* Spending more time examining the question first allows people to deepen their understanding of the question and of the views of others.

Bohmian Conversations suggest patterns that, at first, do not aim for either solutions or arguments; rather, they aim to simply understand where each participant *is coming from*. That is suggestive of an IBIS conversation pattern that simply aims to elicit answers to a prime issue, without any arguments; let us call that the *Bohmian Conversation Pattern*. We use it to "see where people are coming from" without the debates.

Our knowledge federation process is like the opening moves in a Bohmian Dialogue; no prejudice is put on facts, concepts, or assertions by acts of federation. There will be plenty of time for humans to bring their ideas into the conversation. That is where Gordon Pask's Conversation Theory comes into play.

2.3.3.2 Gordon Pask's Conversation Theory (CT)

Pask takes a psychological view of learning, distinguishing the individuality of conceptual systems (Scott, 2001). In CT, distinctions are made between knowing *why* and knowing *how.* Knowledge is *critically about the coherence (and hence, reproducibility) or otherwise of conceptual systems* (Scott, 2001). In a skeleton learning "cycle", a teacher answers "why" questions, then answers "how" questions. CT abandons the concept of learning as a one-to-one mapping of real world to mental categories in favor of a dynamic, internal, self-organizing process of coming to know, interactively with other learners (Rocha, 2001). We begin to see connections between Gordon Pask's ideas and those of complex, adaptive systems; teasing out of the literature the nature of those links would be the subject of an important research program. For now, we are beginning to see more evidence to support an assertion that a boundary infrastructure must serve the needs of a complex, adaptive, learning system.

A conversation is described in terms of an *entailment mesh* (Scott, 2001; Heylighen, 2001; Rocha, 2001). Such a mesh is formed from clusters of concepts, where the clusters represent the existence of relations between the concepts (topics) they contain, illuminating the notion that *knowledge of one topic entails knowledge of other topics*. An entailment mesh is a coherent

bundle of concepts (Rocha, 2001). Coherence within the mesh is *always evolving*; knowledge in a learning environment is dynamic (Scott, 2001).

In *Learning Conversations,* Harri-Augsteine and Thomas (1991) extend the skeleton learning cycle by extending the conversation into the "how" of learning itself. That entails reflection on learning skills and experiences, and on the purposes of learning. The process now involves both the "how and why" of the topic, and the "how and why" of learning itself.

Pask and his colleagues developed methodologies for modeling knowledge, consisting of collections of topics related to one another. The two basic forms of relations are *entailment* relations (hierarchical) and relations of *analogy* (heterarchical—structured as a network). (Scott, 2001). Entailment structures model the "why" component of knowledge. *Task structures* model the "how" component of knowledge; they show "what may be done".

Although the conversation metaphor fits well with social construction of knowledge, it also serves well when the individual is having an internal conversation, weighing different points of view (Heylighen, 2001). At its core, CT invokes a speaker-listener, teacher-learner model in which the speaker/teacher has not only a domain model that drives what is spoken, but also a model of the listener/learner's domain model. These two models are combined as the story unfolds, as the speaker/teacher talks. A good teacher knows better than to lecture on quantum mechanics to a child except in terms the child is thought to understand.

Given the model structures held by speakers and listeners, CT provides a model of the way in which coherence is achieved in understandings. Concepts are exchanged, combined and recombined in a construction phase with the aim of achieving agreement about shared meanings in a coherence phase (Heylighen, 2001). IBIS conversations might thus be viewed as Paskian conversations. We do not suggest that an entailment mesh appears while a conversation is in its *elicitation* phase; we suggest that entailment meshes may emerge during a later *reflective* phase of the conversation.

2.3.3.3 Delphi

Imagine entering a voting booth and, instead of selecting from a list of candidates, instead, voting on the value of some assertion, say, about the environment, and typing in an explanation of your response. That is an elicitation approach known as Delphi. Linstone and Turoff (2002, p5) characterize four phases (also called *rounds*) of Delphi. The first phase is an exploration of the subject wherein each individual contributes pertinent information. Phase 2 seeks an understanding of how members view the issue, finding where they agree and disagree. If there is

significant disagreement, then a third phase seeks to flesh out the reasons for difference and possibly evaluate those reasons. The final phase produces an evaluation of all resources gathered during earlier phases.

The Delphi method, known as a *consensus method* (Fink et al., 1999) was invented in 1948 and evolved during the 1960's at the Rand Corporation (Gordon, 2002); Anonymity was required in the sense that no participant knew the identities of other participants; true debate independent of personalities was facilitated (Gordon, 2002). Questionnaires are passed to each participant asking their opinion of some situation or issue. Analysis of the responses determines the range of opinions expressed. In the next round, the range of opinions is presented, asking for reasons for the extremes detected. A synthesis of reasons forms the basis for a third round of questions. The questions might ask for reassessment of positions expressed, solicit refutations, and so forth. A Delphi is considered complete when a consensus emerges, or when further rounds are not considered useful (Fink et al., 1999).

Two issues with Delphi are the workload and responsibility placed on the leaders (Fink et al., 1999), and time required performing the rounds (Gordon, 2002).

Delphi has experienced an evolution towards Real Time Delphi (RTDelphi) (Gordon & Pease, 2006). From the explanation found at the Website[12]:

> "The studies on this web site rely on expert opinions and use a new version of the Delphi method known as Real Time Delphi. In classical Delphi, the judgments collected in one round are fed back to the participants in subsequent rounds. By contrast, Real Time Delphi is roundless and answers generated are fed back to participants in real time. As in classical Delphi, participants are anonymous to one another and may omit any questions they wish. Anonymity is preserved and none of your answers will be attributed to you."

An RT Delphi consists of a series of statements to which one can register a numeric sense of agreement between 0 and 10 similar to PCT explained above, followed by an opportunity to explain the reasoning behind the response. The explanation takes the form of a textual explanation given in one or both of two text areas; one titled *Negative*, and titled *Positive*. The relevance of the explanation lies in terms of the *consequences* of the item on which a vote is cast. As an example, in the context of future economic systems, one is asked to vote on an item which reads "Non-ownership, as distinct from private ownership or collective/state ownership. A current example is open source software." One is voting on the importance of that item, then one explains the consequences of that item that lie behind the vote.

[12] RTDelphi Website: http://www.realtimedelphi.org/

Delphis suggest patterns that include anonymous participants. A presumed value in that pattern is that personalities do not become the focus of any other participant's attention. Byron Reeves and J. Leighton Read (2009) suggest several important values (patterns) related to a participant owning an *avatar*. Their explanations (2009, p, 64) are grouped under the rubric *Self-Representation with Avatars*. One of the points, Avatars Increase Engagement (2009, p. 65) is explained:

> "Although the psychology of self-representation is new, there is good evidence that the engagement people have with avatars is substantial, eve if unconscious. Avatars can dramatically change how people experience media."

Perhaps this suggests a *Self-Representation Pattern*. However, Delphis do not suggest quite the same thing: anonymous participation in Delphis does not imply need for an avatar; to use our analogy, a Delphi is more like a voting booth, which contrasts with an IBIS conversation potentially more like a combat zone. Avatars may be quite useful in some IBIS conversations.

Delphis also suggest an iterative pattern, in which responses to a first round of questions are reviewed in preparation for successive rounds of questions. Real Time Delphi reduces an ordinary Delphi to one round, in which a statement is asserted, and participants are asked to rate their level of agreement with it on a numerical scale, followed by entry of a description of their reason for their rating. Certainly, the numerical rating pattern is worthy of consideration.

2.3.3.4 World Cafés

> ""World Café" is a concept that evolved out of conversations and experimentation one evening at the home of Juanita Brown and David Isaac". –Nancy Margulies (Co-Intelligence Website)

The Brown and Isaacs book (2005) describes a means of conducting c*onversations that matter.* They describe the literal use of a café, setting tables for typically 4 people, using the table cloth as a shared display on which table participants can write, doodle, and otherwise represent the dialogue conducted at the table. A café is leased for an evening to satisfy a particular goal, say, conducting dialogues about climate change. Participants settle at various tables, dialogues begin, and, after a prescribed period of time passes, all but one participant at each table migrates to different tables; the dialogues then continue with new participants—each table deals with one particular question which remains "on the table" when participants migrate. At the end of a session, each table is invited to contribute a summary of its work to a shared display of all results.

Brown and Isaccs (2005) enumerate the seven design principles as:

- Set the context

- Create hospitable space
- Explore questions that matter
- Encourage everyone's contribution
- Cross-pollinate and connect diverse perspectives
- Listen together for patterns, insights, and deeper questions
- Harvest and share collective discoveries

A theme that pervades writing about cafés is that of *deep listening*. Sometimes, *talking stones* exist at tables; one is not permitted to speak until one has possession of a stone. We see a connection between David Bohm's dialogues and expected or desired behaviors at a café.

An issue with the work products of cafés is possible heterogeneity. Participants scribble on the table cloth. The nature of that scribbling is subject to wide variance. In order to federate cafés, one imagines that a scribe of one sort or another will need to perform some mappings or translations to a format suited for federation. Perhaps a Compendium facilitator is indicated…

World Cafés are suggestive of patterns related to conversation size; while World Cafés are typically face-to-face affairs where conversation size really matters (typically 4 to 5 participants at a *table*), it is reasonable to consider research into conversation size in online conversations.

2.3.3.5 Kelly's Personal Construct Theory (PCT)

Another elicitation system, similar in many respects to RTDelphi is Kelly's Personal Construct Theory. At the root of George Kelly's theory is the *person as scientist* (Kelly, 1955). Humans are seen as creating and maintaining *constructs* or hypotheses about their worlds, always updating those constructs as history unfolds. The use of *repertory grid methods* (Shaw, 1980; Shaw & Gaines, 1998; Gaines & Shaw, 1996) to elicit the world models of individuals relates closely to our interests.

Elicitation in the repertory grid includes presentation of dichotomous issues, where one performs the equivalent of moving a slider along a scale, say, with the middle indicating a neutral response, and either side indicating some degree of agreement or disagreement or otherwise indicating a range of values. An example related to our work would present a statement such as *CO2 Affects Climate*, and a user would be presented with a scale ranging from, say, -1 (disagree) to +1 (agree). While different scales may apply, this approach is similar to the voting selections of RTDelphi.

2.3.4 Conversation Frames

> "It seems to me that the ingredients of most theories both in Artificial Intelligence and in Psychology have been on the whole too minute, local, and unstructured to account–either practically or phenomenologically–for the effectiveness of common-sense thought. The "chunks" of reasoning, language, memory, and "perception" ought to be larger and more structured; their factual and procedural contents must be more intimately connected in order to explain the apparent power and speed of mental activities." –(Minsky, 1974)

The Compendium platform includes several *stencils* which are XML files that suggest frameworks for structuring conversations. Notable among them are those named "Jackson Problem Frames". From (Bjørne et al., 1997), these are based on *Problem Frames*. The authors characterize them in the context of software development in terms of *the set of application Domains, the set of Requirements and the set of Designs*. Three of the domains listed in the Compendium Jackson stencil are Causal Domain, Designed Domain and Requirements. (Bjørne et al., 1997) describe an Information System Frame, which exists if there is an available model of the "real world", expressed in terms of the information domain's *atomic or composite individuals*. This frame expresses system requirements in terms of data collection, data storage, queries and data creation.

We interpret that description as a pattern language that aggregates a particular set of patterns. We also see them as Marvin Minsky's Frames (Minsky, 1974). Minsky's frames are discrete information structures, one for each concept—topic in our vernacular. Each frame is given an identity and serves as a container for attributes (properties) of the concept represented. Here is a trivial example of two Minsky-style frames:

```
Subject id="534"
      Names:      "gas"
Subject id="789"
      isA:        #534
      Names:      "greenhouse gas"
```

Each "Subject" is a frame. Each is identified by an "id", and each contains one or more "slots" (the name given to properties represented in frame structures). Each slot can contain one or more "values". Frame-like representation is a core pattern in much of the artificial intelligence and Web ontologies communities.

Through the lens of conversations, there may be particular requirements, or patterns—*structures*—that are entailed if a conversation is cast within a Jackson-style frame.

Drawing simply from the table of contents of (Hanson, 1958), we see the potential for the following frames:

- Observation—where the conversation deals with measurements and their accuracy; clearly we see evidence that measurements remain in doubt for some participants in the climate debate
- Facts—where the conversation seeks to elicit the facts of a situation; important to the climate change debate: is it a fact that climate is changing? In what ways is climate changing?
- Causality—arguably a focus of the current climate change debate; what's causing climate change?
- Theories—an important focus of debate: how do you explain causality in climate change and predict future climates?

From arguments found in many of the debates related to climate change, the following additional frames are suggested:

- Models—closely related to theories and to observations, models tend to be the center of some debates
- Authority—debating authority appears to be an important aspect of debate: challenge or block authority

We believe that conversation frames facilitate *anticipation* (Rosen, 1985). The nature of an anticipatory system is that of holding a model of some environment and forming expectations based on that model. The simple single-celled organism holds a model of its environment which suggests that a chemotactic gradient means food; the animal swims in the direction of increasing signal and achieves a goal of feeding. In an analogous sense, if we are to identify a particular conversation—or branch of a conversation—as existing in a, say, *causal frame*, then we form expectations of how that conversation should be structured. If there is a causal frame detected, we may seek a theory frame that goes with it. We might ask: "Is there a branch in the conversation tree nearby that suggests dialogue related to a theory?"

2.3.5 Rhetorical Structure

Rhetorical Structure Theory (RST) describes a *major aspect of the organization of natural texts* (Mann & Thompson, 1987). Rhetorical structure is formed through *rhetorical relations*, examples of which are *hypothesis*, *motivation*, and *evidence*; they are like conversation frames. We believe that the connective relations suggested by the IBIS link types serve the purpose of some rhetorical relations. Finding rhetorical structure patterns in individual IBIS statements is a target for this research.

Evidence for the use of rhetorical structure is found in the hypothesis-evidence structures in scientific discourse (de Waard et al., 2009). That study proposes *the construction of a system where a specific scientific claim is connected, through trails of meaningful relationships, to experimental evidence*. Amanda Stent (2000) explores the use of rhetorical annotations, tags, to illuminate structure in recorded spoken dialogues. These findings suggest another IBIS pattern, that of tagging IBIS conversations with rhetorical relations not distinctly articulated by the arcs that connect each node. Compendium, as we shall see (§4.4.3), supports tagging. We say more about rhetorical structure patterns in the next section.

2.3.6 Contributions of Structure

In the implemented and emerging merge agent for the Bloomer platform (§4.2), we describe a rule-based same-subject detection system. In this section, we make reference to a *conversation reader*, which is described as a software platform that reads sentences found in IBIS nodes and applies varieties of analytical methods to those sentences. Later, we will describe that reader as a *merge agent,* part of our research software platform. Where we shall take the notion of such a reader will be described under the name *anticipatory conversation reader*. Only fragments of such an artifact exist at this time, but we include the concept in our research. Let us begin by re-imagining the three kinds of structure in conversations, each different in nature:

- Conversation structure as imposed by the IBIS rules of engagement that entail asking and answering questions, and offering arguments.
- Structural expectations formed by framing conversations.
- Rhetorical structure, which entails argumentation patterns: how a conversation is conducted.

For all the reasons of heterogeneity, signals, noise, frames, and linguistic freedom, conversations are complex. We believe that the different structures allow an anticipatory view to be formed, one that is at once complex and adaptive. We do so since we anticipate that the rule-based merge agent we shall describe below (§4.2) could run up against fundamental limits associated with rules being expressions of linguistic theories or language models, and there simply may not be enough of those expressible in a finite rule-based system to satisfy more complex conversation merging needs.

Following is a sketch of an artifact we name *anticipatory conversation reader*. We start with a known context, and we watch as the conversation unfolds, using hints based on varieties of

structure to continuously refine a working hypothesis of what is being stated at each node. Let us imagine a design-level conversation in which an anticipatory conversation reader might operate.

In some sense, we are describing the equivalent of a continuously refined hypothesis, one for each node; each hypothesis is first formed on a basis of all that is known at a given place in the tree, and later refined through satisfaction of expectations. What does that mean? (Benn, 200) articulates a particularly interesting scenario that describes this opportunity:

> "In the two case studies an approach of manual ontology-based representation is used, where the information contained in plain-text source material describing a particular scholarly debate is coded by a knowledge modeller as instances in a knowledge base that correspond to actual elements of the debate as described in the source material. These ontology-based representations can then be analysed to detect important macro-level features. and such results can then be revealed to any subsequent user of the system not necessarily the same person as the knowledge modeller who aims to learn about and engage in the chosen knowledge domain. Note that this approach suggests two distinct roles the knowledge modeller, with some level of domain expertise, contributing to the system, and the end-user, with perhaps less domain expertise, gaining insights from the system. However, […], in practice this distinction may blur as knowledge modellers gain new insights through the work of interpreting source material to code in the knowledge base and end-users, through increased domain expertise over time, can extend the existing knowledge base through their own modelling of new source material."

Substitute a topic map for the term "knowledge model" in that passage and a vision of our socio-technological infrastructure is in place. Benn's *new insights through the work of interpreting source material* corresponds to the behaviors of anticipatory conversation readers, particularly when feedback on results returns from the user community and the reader adjusts its behaviors.

To anticipate implementation-level dialogue, consider the case where nothing is known about a particular IBIS statement being read, but it has some identifiable words or terms from which to construct a conceptual representation, a new topic in the map. The conversation reader would create such a subject, link it to this node, and then use what is learned over time to improve the new topic's representations—adding new properties, new relations, and so forth. This is a page out of the machine reading literature (Etzioni et al., 2007; 2008). The open source OpenDMAP[13] (Hunter, et al., 2008) rule-based parser is available for use in such an implementation. An as-yet unexplored (in this research) platform for linguistic analysis is IBM's open source UIMA (Unstructured Information Management Applications) project[14] (de Chalendar, 2009).

[13] OpenDMAP: http://opendmap.sourceforge.net/
[14] UIMA: http://incubator.apache.org/uima/

In the conversation thus far, we sketched a rule-based implementation of a conversation reader that backs up a merging (federation) platform (discussed below). Rules imply a language model is at work; to entail a range of language models is to create a range of rules. Google has shown the ability to use statistical learning processes to perform translations without rule-based language models (Och, 2006), which suggests that our options extend beyond rule-based language models.

Before we introduce our research platform, we provide a short example of its use, then describe a larger scenario in which sensemaking is performed using the entire platform.

3.0 An Illustrative Scenario

Research related to complex adaptive systems suggests that there are patterns of sensemaking appropriate to our thesis. They are:

- Tagging—marking trails with simple signs and symbols
- Annotating—more-detailed trail marking
- Storytelling—wiring discovered ideas, questions, and arguments into coherent, contestable stories
- Conversation—conducting investigations related to contested findings
- Reusable building blocks—viewed in this light, those would be the discrete subjects represented in our topic map

In this section, we offer another springboard story, and then follow that with a scenario that paints a larger picture of participants using our socio-technological infrastructure. In our latest springboard story, with illustrations, we view the early actions of a user discovering and entering an IBIS conversation.

> A researcher is attracted to the Millennium Project's 15 Global Challenges[15], and visits our prototype platform to discover an opportunity to engage in an IBIS conversation around one of the challenges, an issue (Figure 7).

[15] Global Challenges: http://millennium-project.org/millennium/challeng.html

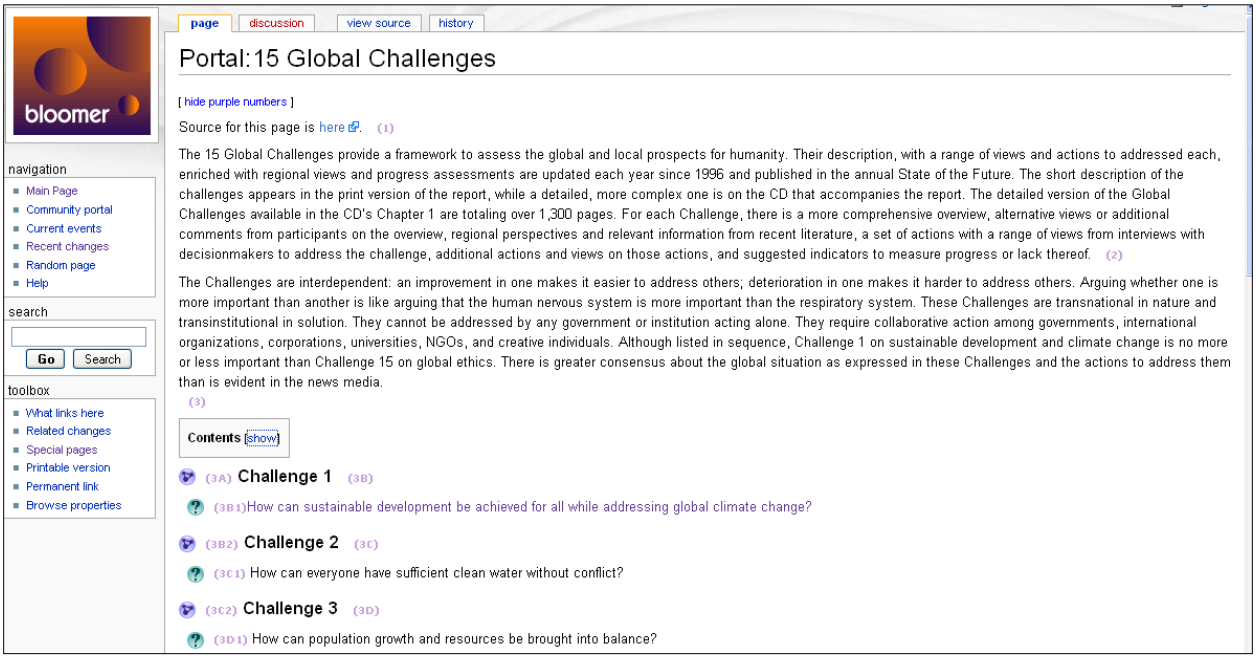

Figure 7: Bloomer Prototype Global Challenges

The researcher selects a challenge, clicks on the link related to the chosen issue, and enters the conversation. [Note: at this point, we have exceeded the limits of our platform's demonstrable capabilities, so we illustrate the rest of the story using scenes from two other platforms: Debategraph and MIT's Climate Collaboratorium]. On entering the conversation, the user has the opportunity to respond to the selected issue, or to navigate elsewhere in the conversation and ask or answer questions or enter arguments. Illustrations of conversations in progress are Figures 8 and 9.

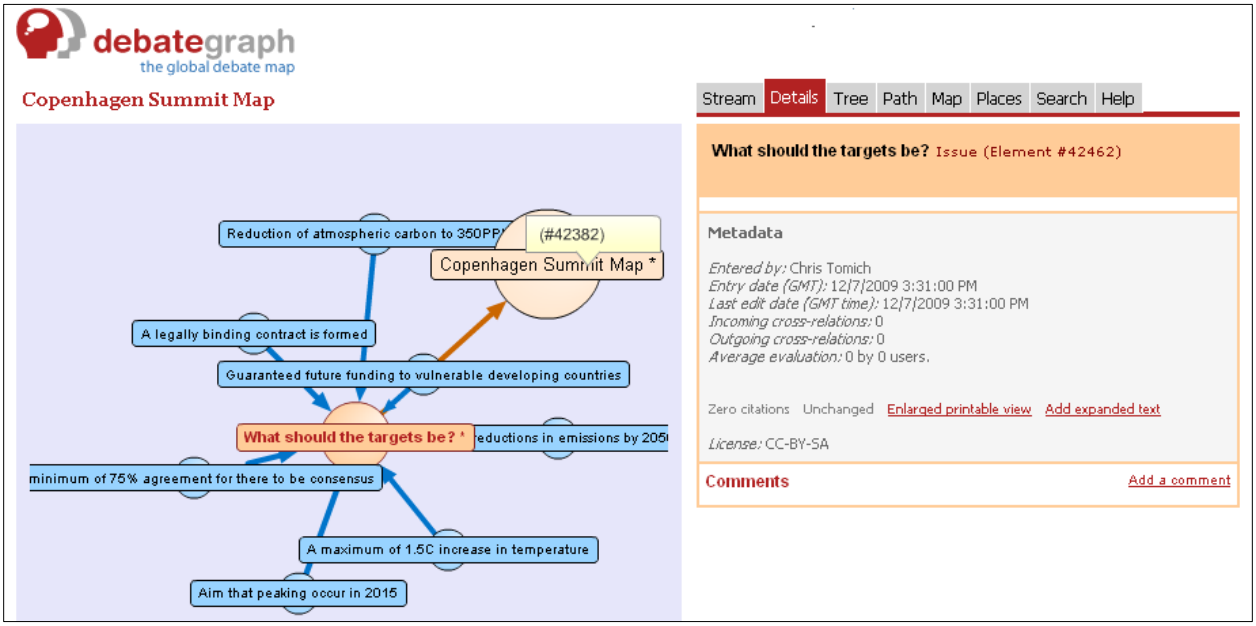

Figure 8: Debategraph Copenhagen Summit Map

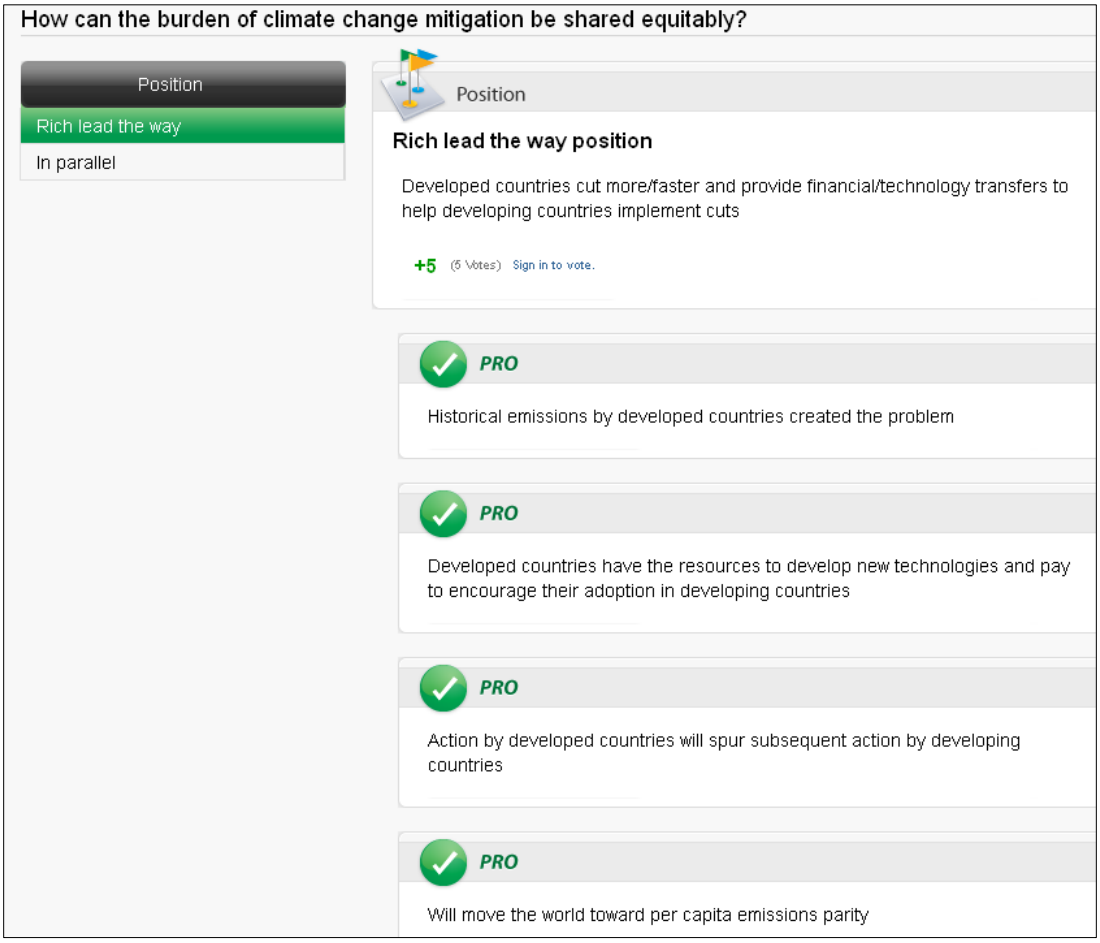

Figure 9: MIT Climate Collaboratorium

In the following scenario, we focus on conversations and storytelling. Consider Figure 3 above, which presents the largest possible view of this research and nearby research-related issues. The issue map begins by articulating a temporal sequence: *sensemaking→decision making→journalism*. This flow suggests that facilitating the process of taking the story behind the decisions to larger audiences is an appropriate target for sensemaking in the first place. The map then presents one view of sensemaking processes as this:

1. Elicitation of conversations—many types, many occurrences
2. Federation of those conversations
3. Reflective re-interpretation of those conversations (together with whatever else is known to the sensemaking communities).

We next describe those three sensemaking processes in sufficient detail to gain an image of the relationship between our research, which is focused on the federation process, and human-centered sensemaking processes in the large. In this explanation, we will introduce *patterns* of

behavior, about which this report will speak in more detail below (cross-ref to Section X). In this scenario, we will introduce numerous terms without specific definition; each term used here will be the subject of discussion later in this report.

3.1 Elicitation—Conversations

We imagine a scenario that opens as follows: Real-time Delphi (Gordon & Pease, 2006) is used to ask participants to rank in terms of importance several issues. Examples of issues to rank might include, for instance:

- Sensitivity of climate to greenhouse gases.
- Sensitivity of global economic systems to deleterious climate change.
- Means of using market forces to shape human behaviors.

Indeed, RTDelphi might have followed several instances of World Café (Brown & Isaccs, 2005) sessions during which participants created those issues. Once issues have been organized into an ordered sequence, we then place those issues before numerous instances of IBIS conversations, where small groups of individuals participate in expanding on each issue, one at a time.

Some of those IBIS conversations might be held in face-to-face situations, facilitated, say, using Compendium. Others might be conducted online e.g., in Debategraph, Deliberatorium, Cohere, or one of the installations expected to result from this research. Some conversations might be among invited domain experts, others among self-selected individuals. One aspect of the choice to conduct many such conversations is the quest to gain access to the worldviews and insights of a wide variety of expertise and personal experience. One imagines members of the legislative communities, members of the clergy, and members of a many different domains of expertise engaged in these conversations.

We extend the range of participants to include members of classrooms, perhaps the main limitation being the ability of those participants to actually participate in a global conversation—such decisions are perhaps best left to the schools and teachers who would facilitate that participation.

Let us introduce a pattern to the elicitation processes. The pattern is called *deep listening* as found in the World Café literature. To implement that, World Cafés frequently rely on a *talking stone*: to be able to speak at a table, one must be holding a stone. A talking stone is related to another pattern, *taking turns*; it provides opportunities for deep thinking while waiting and listening. In an online IBIS conversation, a *window of opportunity* might control users' ability to

contribute. Open the window for a period of time (permit authentication and access to response forms), then close it for a period of time. Some participants will use that time wisely to reflect on the conversation and perform background research, others will not. A reputation and trust system might enter play such that poor answers result in fewer, if any, gains in reputation through contributions.

We imagine opening a first window on the initial issue with the restriction that answers to the question (positions that respond to the issue), or questions that seek to refine the issue, are permitted. Any other IBIS response is considered non-responsive and is deleted—the responder losing reputation points for poor behavior. Leave the window open for a specified period of time such that all participants have time to consider their responses. Then close the window and leave it closed long enough for serious contemplation—deep listening.

A following window opens. Its opening rules will depend upon whether questions were asked in the first window. If so, the new event requires elicitations of responses to those questions only. When all issues have positions, then the window of opportunity to debate begins.

3.2 Conversation Federation

We now have a possibly large collection of issue maps, each related to the same issues. As we shall describe later, we now have a body of information resources that ready to be federated. To anticipate, each issue is the subject of possibly numerous issue maps. Each map thus has an unknown number of nodes that are *about the same subject*. Our thesis states that nodes that are about the same subject must be federated. We do so to reduce navigation overhead to find all the responses to the same issue. When we federate those conversations, we combine (merge) IBIS nodes that are found to be *saying the same thing*. We seek to eliminate duplicate nodes in a possibly huge IBIS conversation.

The result of this federation process is the smallest possible collection of IBIS nodes, though the resulting graph may still be far too complex to present all in one view. That issue speaks to the need to *re-factor* an IBIS graph into smaller graphs; that process is not a part of this thesis research, but it remains a necessary component of any large IBIS conversation boundary infrastructure.

3.3 Reflective Re-Interpretation—Storytelling

> "Discovery consists in seeing what everyone else has seen and thinking what no one else has thought." –Albert Szent-Györgi (1937), Nobel Laureate in Medicine

An IBIS conversation elicits and represents a graph of questions, answers and arguments. In some cases, the conversation reflects a debate. In other cases, it reflects a sequence of thoughts, as are the cases when one uses an IBIS conversation to, say, plan a thesis project. The conversation exists in a particular context; it emerges using particular questions, particular answers, and particular arguments. We now ask this question: if taken out of the context of the IBIS conversation, what else might those questions, answers, and arguments say if they were wired into different stories?

The inspiration for this question lies precisely in the story behind the Cohere platform. Cohere facilitates two basic behaviors: capturing ideas, questions, and arguments sometimes absent any particular context. Those ideas are captured simply by annotating Web pages or creating *de novo* Cohere nodes (ideas). In fact, at the sensemaking portals of the future, it is reasonable to expect that IBIS conversations, social bookmarking (tagging), and Cohere annotations will co-exist. The results of each of those activities are collections of nodes, each node containing a discrete concept, an idea, a question, or argument.

That is the backdrop for reflective re-interpretation, an analytical process modeled after *jigsaw puzzles* with the following twist: in a conventional jigsaw puzzle, one has the box with the picture. In this new rendition of that familiar game, we have a "pile of ideas" but no picture.

This is a game of discovery. In one manifestation of this process, all IBIS and Cohere nodes are stripped of their original context—they are displayed in such a way that their original context is not visible. Participants are then encouraged to use Cohere to wire those nodes into whatever stories make sense to them. In doing so, it is possible that one would discover that one node originally created in an IBIS conversation contradicts another one, perhaps even in the same conversation.

The end result of this exercise might best be viewed with a toggle switch that flips views. Open an IBIS conversation in a graphical view, then flip the switch and see the same nodes wired in different ways. Computers are no match (thus far) for the vast visual comprehension capabilities of humans, but their ability to assemble large masses of information for human visualization remains unmatched in humans. We presented this scenario to develop an image of one of many possible scenarios our socio-technological infrastructure will support as it evolves. Demonstrating this particular scenario as a developmental exercise is not planned.

The tie that binds elicitation of ideas to their later evaluation is the process that condenses a possibly large volume of conversational information, which is collected as discrete ideas, into a

uniform collection of non-redundant human assertions. That process is the federation technology described in this report.

4.0 Contributions

Before we proceed, a reasonable question to ask is this: isn't this problem already solved? We anticipate questions of this type: *What about the Semantic Web? Doesn't it already perform federation?* Our response to any question related to the relationship between this research and the Semantic Web suggests two observations:

- Knowledge federation, as we define and implement it *can* be a part of the Semantic Web
- The Semantic Web is best described (Berners-Lee et al, 2001) as an infrastructure composed of formal representations (ontologies) that facilitate agent-based computing on the Web. This means that, using standard terms for naming, identifying, and relating things on Web pages, e.g. cameras, cars, hotels, and so forth, various software agents and search engines can roam the Web looking for answers to questions or building more accurate indexes.

Another view is to step back from the Semantic Web and just consider IBIS conversations alone. Many research projects begin by identifying a deficiency in some product, some algorithm, or some discipline and set about to fix that deficiency. We see no deficiency in any of the many IBIS platforms; rather, we believe that value can be added by federating IBIS conversations that can be shown to be *about* the same issue.

A human-computer ecosystem includes people and computers. This chapter is about the computer infrastructure. As we shall outline in the following sections, our research suggests that it is possible to fabricate an appropriate boundary infrastructure that serves as the computer side of a human-computer ecosystem. We propose to demonstrate an improvement to existing and emerging IBIS conversation technologies. What all of that means will become clear as this report progresses. We view this claim through a lens of *crowd sourcing* to see that the infrastructure offers, at once:

- A controllable environment—one can choose one's crowd
- Serves as a coordination system—coordinates the elicitation of world views across spans of time, cultures, and distance
- Structured discourse that supports argumentation
- Opportunities to enforce *rules of engagement*—patterns of behavior
- Future opportunities to surround IBIS conversations in procedural structures, e.g.

- Issue elicitation
- Position elicitation
- Argumentation elicitation
- Conclusion elicitation
- Reflection on the resulting structured conversation
  - Annotations
  - Wiring annotations with coherence relations
    - Storytelling based on the conversation

To anticipate the nature of our contributions, we summarize them as follows:

- An IBIS Conversation Pattern Language—a collection social/behavioral patterns necessary to hold structured conversations in a human-computer ecosystem. The specifics of those patterns, to be partially described here and discovered in more depth in our research, involve the engagement of humans with computer mediation using a particular *boundary infrastructure* we will describe here and develop in our research. We believe that such a pattern language is a required component of a conversational ecology.
- Extensions to topic mapping in the form of *virtual merging technologies*, aimed at satisfying the need to merge conversations without losing the separate identities and semantics of individual conversation contributions. A proof-of-concept extensible, evolvable platform to support both further research and live IBIS conversations *in the wild*. We believe that the boundary infrastructure of which our merging technologies are a component, can serve as the technology side of the human-computer ecology anticipated in Research Questions 1 and 2.

Potential contributions beyond those two might come in the form of implemented NLP (natural language processing) routines that support manipulations of particular statement forms as a part of merging platform, perhaps an implementation of the anticipatory conversation reader. We expect to see and include other pattern contributions by way of the literature and as appear during our research trials, but those which we invent during our own research will be claimed as contributions; others simply enter the resource pool for a more robust collaboration facility.

Our contributions will be incorporated in a sensemaking platform to be used by combinations of scientists, students, teachers, and other interested stakeholders in the unfolding universe of discourse that faces humankind in the future. In the following sections, we outline the technical

aspects of the particular boundary infrastructure we are constructing. The TopicSpaces platform has been in development for several years, continuously evolving through new generations.

We intend to facilitate user-fabricated boundary objects for the conduct of IBIS conversations. The core component of our platform is a *subject map provider*[16], a software platform that behaves as an intelligent database which advertises an API suitable for a variety of sensemaking activities. At core, it is a map, and maps typically advertise these API features:

- Put—insert or update some information resource in the map
- Get—fetch a particular information resource from the map
- Remove—remove a particular information resource from the map
- Query—answer structured queries to locate information resources in the map

Using that API (see Figure 10 below), it is possible to craft agents that advertise higher-level APIs such as those associated with the manipulation of nodes in an IBIS conversation (see Figure 11).

Our project is called TopicSpaces, an open source (Java) subject map provider under development prior to this research and adapted to satisfy research needs. The work reported following this relates to TopicSpaces. Terms used are these:

- SubjectMap—a container for representations of subjects as defined by a particular Legend. An implementation of a legend is also known as an *application.* SubjectMaps can be defined by more than one Legend.
- Legend—a public disclosure of property types used to identify subjects in a particular SubjectMap together with the rules necessary to compare subjects
- SubjectProxy—a container for representations of individual subjects in a SubjectMap; proxies are containers of SubjectProperty objects.
- SubjectProperty—a *key-value* pair, where the *key* is a property type defined in the Legend, and *value* can be either a singleton or a collection of values
- *Application*—Another name for an implementation of a particular Legend. Some examples are Legends that define people, or places, or events.

At the implementation level, maps, proxies, and properties are Java classes. Outside of the map's implementation, TopicSpaces includes classes that manage persistence (database), and support a *society of agents* architecture; most of the map-building and maintenance functionality

[16] Subject Map Provider: we use the term "subject map" for our implementation of a topic map platform

in TopicSpaces is implemented as *plug-in agents*.

We next sketch the overall architecture of TopicSpaces, then follow with a description of the TopicSpaces *merging agent*.

4.1 TopicSpaces Architecture

TopicSpaces is described as an open source knowledge representation and organization server, capable of providing search and knowledge management services using HTTP and XML/HTTP protocols that service HTML, JavaScript Object Notation (JSON)[17], XML and possibly other resource formats. Faceted search, caching, replication, Web administration, and other capabilities are available through suitable extensions to the core platform. It runs in conventional servlet containers such as Tomcat[18] and Jetty[19]. In this research, we focus on its application to IBIS conversations.

4.1.1 Core TopicSpaces Subject Map Provider as Device Driver

At the lowest level, the TopicSpaces Subject Map Provider behaves as if it is a very low-level *device driver* as illustrated in Figure 10. At this level, it advertises a simple map API as discussed above. Figure 10 illustrates core agents suited to satisfy the minimal needs of any subject map provider: indexing records, managing persistence, and merging. Figure 10 represents the core boundary infrastructure we contribute to the IBIS conversation augmentation inquiry. To be useful, it must be extended.

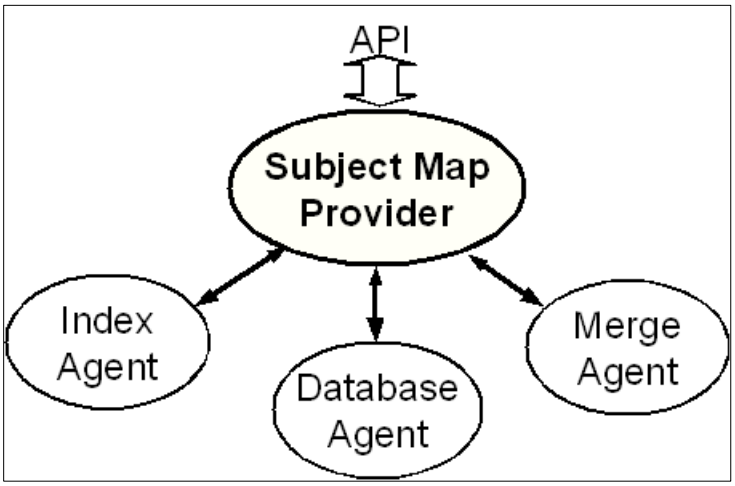

Figure 10: Device Driver Architecture

4.1.2 TopicSpaces Applications

To do useful topic mapping, *applications* must be installed that maintain topic maps according to

[17] JSON: http://json.org/
[18] Tomcat: http://tomcat.apache.org/
[19] Jetty: http://www.mortbay.org/jetty/

particular legends, as illustrated in Figure 11. The figure illustrates an IBIS application that maintains a subject map that represents IBIS conversations. At the same time, the application provides merge rules, as discussed below, to the provider. The application then advertises a higher-level API suitable for dealing with IBIS conversations at the view level.

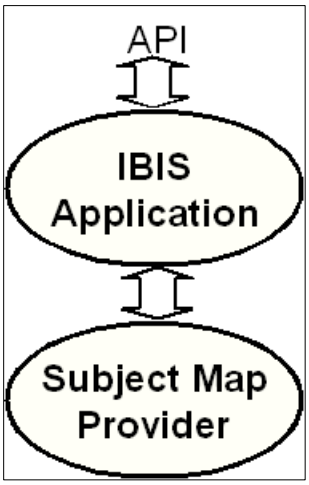

Figure 11: IBIS Application

4.1.3 TopicSpaces Servlets and Service-oriented Architecture (SOA)

We provide a Web presence to TopicSpaces through a servlet, as illustrated in Figure 9. The servlet can be configured to provide access to the IBIS application (Figure 11), and can provide direct access to the core TopicSpaces API (Figure 12) as a Web services interface.

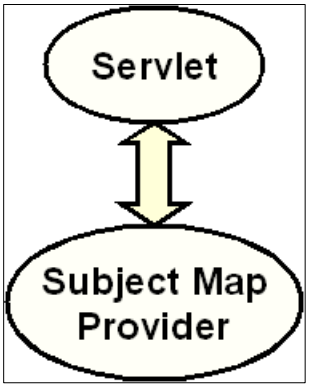

Figure 12: TopicSpaces Servlet

Web services facilitate the federation of many similar platforms by granting direct access to the core APIs. Web services at the application level allow different IBIS platforms to participate in IBIS conversation federations.

TopicSpaces implements a RESTful (Richardson & Ruby, 2007) API for Web services queries over the HTTP protocol supported by Java servlets. A RESTful API is one based on URL strings that include the server URL coupled with elements that direct the server according to the query. With such a URL, the servlet can determine the nature of a query (is it to fetch,

store, update, remove, or query?), what is being sought (e.g. a particular IBIS node), and how the results should be returned (e.g. HTML, JSON, XML, etc). As an example, consider this fictitious RESTful query:

```
http://www.server.org/json/12345
```

That query would return the contents of the `SubjectProxy` identified above (§2.2.2.4) as a JSON (JSON Website) string. The structure of the URL, coupled with the fact that it is submitted as an `HTTP GET` command to the browser, is interpreted to mean *fetch the subject identified as "12345" and return it formatted as a JSON string*.

4.2 TopicSpaces Merging Agent

TopicSpaces is designed to provide the following capabilities:

- Automatic merging capabilities
- Facilitate social processes related to users suggesting merges,
- Facilitate social contesting those merges already made.
- Facilitate un-merging of contested merges

In the following paragraphs, the automatic merging facility is described. Before we examine the details of automatic merge processes, let us revisit the fact that TopicSpaces is performing this work in the context of a social portal in which all processes are maintained as transparent and are contestable. We mentioned earlier the notion of *trust*, which, when viewed as part of a larger *reputation and trust* (R&T) infrastructure, helps all stakeholders to make choices on which resources in the federation satisfy particular needs under particular circumstances. The merge agent system in TopicSpaces is, itself, subject to R&T evaluation, and evolution; where merge rules, as described below, require changes, the capability to affect such changes are available to authenticated and authorized stakeholders.

TopicSpaces presently employs a *rule-based* merging agent. Each rule is installed by the application that creates it. Each application will have its own specific merging needs. For instance, a *Person* application, that is a Legend that defines a subject map the primary subjects of which are human individuals, will need to define merging rules that know how to deal with the specific ways in which that application represents people. During coming stages of research, we plan to expand on the merging agent facilities to incorporate what we have described above as anticipatory conversation reading, a departure from simple rule-based merging.

In the following paragraphs, we introduce the concept of merging with a view towards implementations. In a "typical" topic map merge process, the simplest approach is, visually speaking, to *hold a new proxy in the air and ask if any other proxy can match to it on a basis of identity: Are these about the same subject?* We have the opportunity to use property-based queries to locate all subjects that use the same property types for subject identity (see below). This greatly narrows the field of proxies to test for subject identity equality.

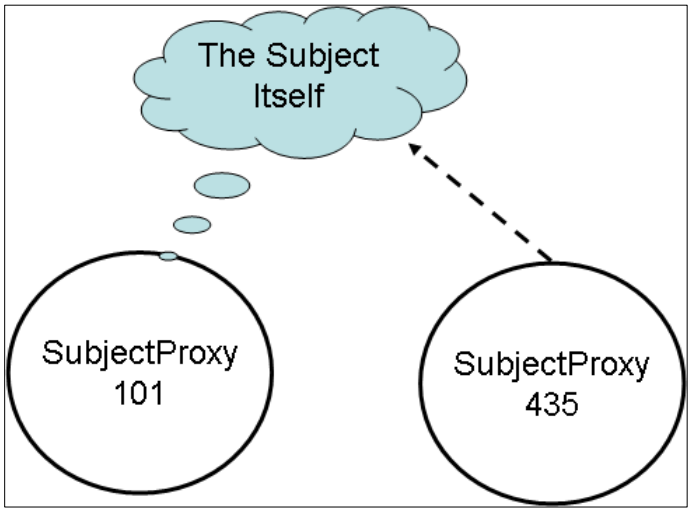

Figure 13: Two Proxies that Represent the Same Subject

When two proxies are found to be the same with high confidence (Figure 13), the typical approach is to perform a *set-union merge* where the original proxy acquires those properties from the new proxy that it does not already contain (Figure 14).

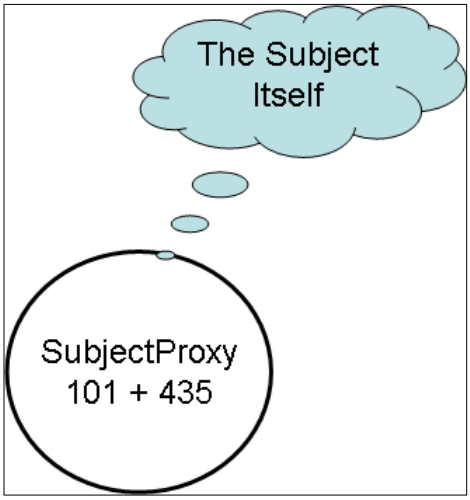

Figure14 : Merged Proxies.

When two proxies are simply *suspected* to be representations of the same subject—that is, when a very weak vote (e.g. a name-based test passed) has offered positive evidence of equality,

then the process is to create a relationship between the two proxies that suggests a candidate merge, and gives the reason based on the rule that fired. For instance, two proxies that carry the same name string, e.g. "Jack Park" are weakly suspected of being representations of the same person. That, alone, is not sufficient to merge the two proxies.

As a final comment on the overall picture of TopicSpaces merge technology, we plan to configure the system to *suggest* merges to be performed and await further instructions from the social component of the federation. Here, one imagines an ability to vote, perhaps along the lines of RT Delphi described below, or perhaps simply a merge approval from designated participants, or perhaps, in the simplest form, a time window closing where no comments were detected to suggest otherwise, at which time an automated merge is performed

4.2.1 Merge Rules

We describe here the entry level approach to merging using rules. Since federation will ultimately call for greater sophistication than the simple rules we describe here, our goal is to create a platform that is *capable* of supporting evolutionary processes of both software and user interface elements necessary to sustain improvements in federating IBIS conversations. The merge rules described here represent *language models*. They presently do not tackle the more complex issues of modeling the structural opportunities suggested earlier, though they will be extended early in this research to include structure detection.

Merge rules in the IBIS domain must be able to identify and compare the identities of nodes, and to *parse* the statement—a non-trivial task. The simplest instance of identity would be to notice that two, say, *Position* nodes say precisely the same thing using the same words and sentence structure, e.g. "Reduce carbon dioxide". That comparison is necessary, but not sufficient. If both nodes are answering the same question (what to do about global warming) in precisely the same way, then they should merge; in that case, the sub-graphs of each merged node must merge according to the algorithm (§2.2.2.4.1) , the issue and its responding position(s). If there are differences, even subtle ones, then a merge may not be indicated.

If two nodes *essentially* say the same thing, e.g. one says "Reduce carbon dioxide" and the other reads "Lower carbon dioxide", then we need sophisticated text handling agents to notice the synonym and determine sentence equality. In a more extreme case, the sentence might be turned on its head, e.g. "Bring carbon dioxide levels down", or another synonym, CO_2 is introduced. We must provide text handling agents to deal with these permutations.

In the case where two, say, positions are found to be saying the same thing, but they are not responding to the same question, then it may not necessarily be the case that they merge. We have more to say about cases like that below.

To summarize, merge rule strategies for IBIS graphs are appropriate for some situations and not for others. In some cases, when a node merge is indicated but precluded by a look at parent nodes, then a graph merge strategy would suggest testing parent nodes for merging. Merging IBIS thus requires graph *merge* and *node merge* strategies.

How does a merge rule appear? In the most general form, it is an IF-THEN rule coded in some language. In the TopicSpaces case, rules are written as Java classes; each rule is then *registered* by its application with the merge agent (described below) for later use.

The simplest rules in TopicSpaces perform tests to see if two subjects are identified by the same identifier property value; in topic maps, that property is known as a Published Subject Indicator (PSI) (Schwotzer & Cebulla, 2006), which takes the form of a Uniform Resource Identifier (URI) (Internet Society, 2005). If two `SubjectProxy` objects include the same `PSI` value, then they are, by definition, representations of the same subject. That rule, expressed in sentences, looks like the following:

```
IF both proxies contain PSI-property values
AND IF PSI-property values for two proxies each contain
an instance of the same PSI value
THEN vote = 5
```

That rule illustrates that merge rules *vote* in favor or against merging in a range (in present experiments) between -5 and +5, with 0 representing *no opinion*. The wording of that rule suggests that code necessary to support the rule must examine *collections* of property values; a typical `SubjectProxy` might include several `PSI` values, each related to some aspect of its identity. For instance, a particular subject might be *owned* (created) by a particular application, so it might gain a `PSI` value assigned to that application's creation. The same subject might gain a `PSI` according to some specification of its identity; a *person*—an individual human being can have a `PSI` that identifies that human as distinct from all other humans represented in a topic map.

More complex rules, such as those associated with IBIS nodes, will necessarily perform other types of tests. Those tests include comparison of node type, and comparison of IBIS statements contained in each node.

4.2.2 Merge Agents

The Merge Rules scenarios portrayed above suggest that we have a need for text handling agents capable of *making sense* out of sentences. There are several aspects of any merge situation for IBIS:

- The aspect that deals with identity properties of each proxy. These include taxonomic/partonomic (hierarchical representations), roles, and specific properties such as identity values
- The aspect that deals with semantics; in an IBIS subject, a specific statement summarizes a node, say, an Issue, e.g. "What shall we do about global warming?"
- The aspect that deals with an IBIS node's context; context, here, is defined as the specific node(s) to which a given node is linked (outbound links), the nature of those links (direction and semantics), possibly tag metadata on nodes, and possibly the broader context in which the map is embedded (e.g. the title of the map).

In the case of identity properties, we are able to write software agents that perform database queries that allow us to compare, property-by-property, those identity properties appropriate to specific merge rules. In the case of semantics, we must write software agents that, essentially, *read* text and make comparisons. In the following section, we examine the core node types: Issues and Positions nodes.

In each IBIS case, node comparison begins with seeking like node types (e.g. issues, positions), each of which can be shown to exist in the same context. Consider a very simple example, two different dialogue maps, each sketched in a text fashion:

- What shall we do about global warming? ← Nothing!
- What to do about global warming? ← Do not do anything!

We have four nodes, two issues and two positions. If we determine that the two issue nodes must merge, then the position nodes linked to them are now candidates for merging. Making such decisions entails text reading code capable of rendering opinions about meanings of short sentences.

4.2.3 IBIS Nodes and Merge Rules

We turn next to sketches of merge issues related to particular IBIS node types. Some of the descriptions that follow relate more to the general topic mapping convention that each subject demands representation in its own SubjectProxy. In that view, we leave the domain of IBIS

nodes as *IBIS nodes*, and think of them as subjects, about which properties and relations besides those of the IBIS conversation can exist. In this research, it is not necessary to chase entailments related to subjects outside the IBIS conversation, but, it is worth noting that the topic maps paradigm avails larger entailment structures around each IBIS node than created in the conversation itself.

4.2.3.1 Issue (Question) Nodes

Consider these Issues:

- What shall we do about global warming?
- What about global warming?
- Is global warming a problem?

At the surface level, they are each *about* global warming. On inspection, we are able to conclude that the third question is not the same as the first two. It poses an *is* question which demands a *yes* or *no* answer (with allowances for a *maybe*). The first two pose a *what about* question; let us offer a determination that the first two questions demand the same class of responses, which would be likely result in multiple *positions* being offered. Still, are they the same question with different words? In some contexts, perhaps yes; in other contexts, perhaps not. In our tests described below, we will use less ambiguous questions.

We posit a set of agents that deal with Issue nodes:

- Determine the context of each node
  - For those nodes that exist in the same context:
    - Determine the question type: who, what, where, when, why, how, and is (are)
      - For like question types
        - determine semantic equality for each node's *statement*

4.2.3.2 Position (Answer) Nodes

Returning to a trivial example:

- Author A: What shall we do about global warming? ← What about oil consumption? ← Reduce oil consumption!
- Author B: What to do about global warming? ← Reduce oil consumption!

We see two different Position nodes that appear to convey the very same semantics. But, we note that they do not exist in the same contexts. In one scenario, we observe that the two Issue nodes could be merged into one proxy for that issue. But, we have entailed sub-graphs from each that are distinctly different, even though both sub-graphs each contain a node that appears to represent the same subject (as based on simple string comparison). Or do they?

If we accept a strict conjunctive set of rules, which might include the following:

- `Same node type`
- `Same context`
- `Same semantics`

then, strictly speaking, the two nodes are different. Technically speaking, the *identity* of the "Reduce oil consumption" position node for `Author A` is this:

reduce_oil_consumption_answers_what_about_oil_consumption,

whereas the *identity* of the "Reduce oil consumption" position node for `Author B` is:

reduce_oil_consumption_answers_what_to_do_about_global_warming.

Different subject entirely. They should not merge.

But…Consider this option: even if each IBIS node is a different subject, each is *about* the same thing: reducing oil consumption. In a topic map outside the conversation, there must be a proxy for that particular subject, one that links to the two IBIS nodes, since each is used in a different context. This means that an external topic map serves to index and track conversations, providing an additional level of federation to conversations: where conversations do not merge, they are still linked through their common subjects.

4.2.4 Developmental Testing

We used the IBIS application to conduct a series of simple merge tests, which we describe next. Our trial conditions are defined in Figure 15.

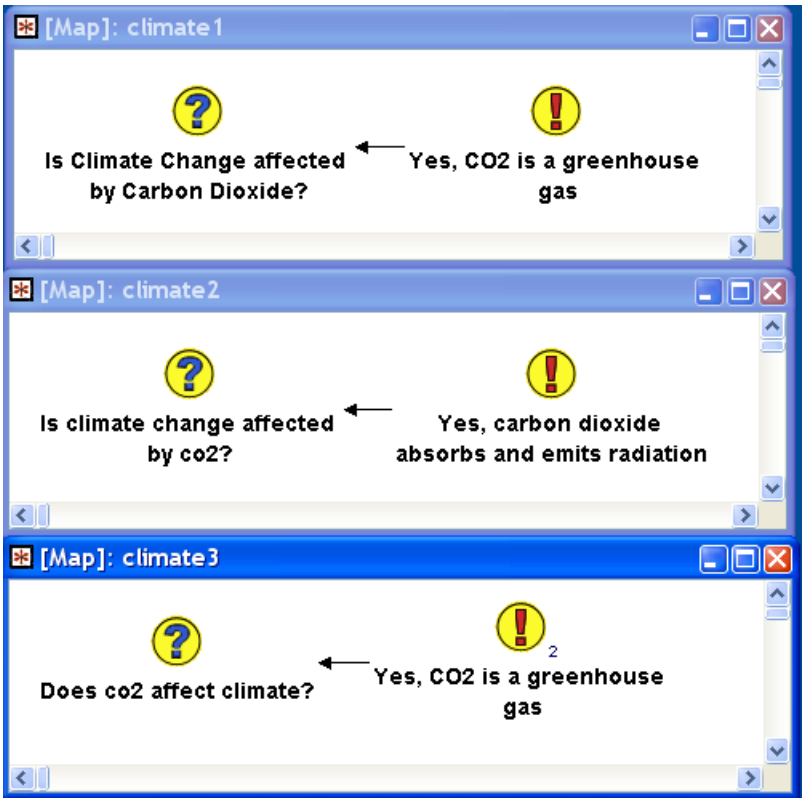

Figure 15: Merge Test Cases

This is the simplest form of match test, in which two questions, one from each map, have been determined to exist in the same context and are thus subject to comparison. An exact match test would return true for the following two strings:

- `Is Climate Change affected by Carbon Dioxide?`
- `Is climate change affected by carbon dioxide?`

The same test would return false for the following two strings, from *climate1* and *climate2* in Figure 15

- `Is Climate Change affected by Carbon Dioxide?`
- `Is climate change affected by co2?`

The exact match test, in this case, is written to be case insensitive. The second test fails even though humans reading the sentences recognize that they are, in fact, asking the same question. The difference lies in two different terms, `carbon dioxide` and `co2`, exist as different strings, though they carry the same semantics. This condition suggests another test that looks at meaning through synonyms or definitions.

4.2.4.1 Simple: Synonym Matching

For the following two strings to match there must be a means by which we isolate miss-matched terms, and then analyze them. In a *Simple Meaning Match* algorithm, we intend to look at synonymy and term definition.

- `Is Climate Change affected by Carbon Dioxide?`
- `Is climate change affected by co2?`

For this test to pass, we would expect to find proof that `Carbon Dioxide` means the same as CO_2. This test raises an interesting issue: *where does the test look for answers?*

The first answer to where we look for simple meanings is the topic map itself. In the presumptive case, the concept "carbon dioxide" will already exist as a subject with that name, and the naming section of that subject proxy should include synonyms.

In the case where such a merge test fails, TopicSpaces behavior should be as follows:

- Generate an *explanation*:
    - Rule x failed due to a difference in the terms "Carbon Dioxide" and "co2"
- Generate a *merge failure report* based on the explanation and attach it to the two proxies for later review. Such a report would be available to view by any user. It may be the case that designated stakeholders take responsibility for merge decisions, but all stakeholders should have access to the system's explanations of its behaviors.
- A speculative concept involving *change listeners* is described below.

In the case where a match is found in those two nodes, the new map would look like Figure 6.

4.2.4.2 Complex Matching

Consider two sentences from *climate2* and *climate3* in Figure 15:

- `Is climate change affected by co2?`
- `Does co2 affect climate?`

A simple string match would fail; isolating the difference between these two sentences does not return just one term: the questions are worded differently. Human readers would recognize them as essentially asking the same question. Human readers would suggest that the two issue nodes be merged. The present thinking on complex matching suggests two approaches:

- User intervention
    - Where there is reason (e.g. context, and partial word match) to suggest possible merge, notify node authors and ask if a merge is appropriate.
- Create text-reading software agents that mimic *story understanding* capabilities; ask them

for opinions.

In fact, we are considering both options. When text reading is the case, we might be able to reform each statement into a logical form:

- `affectedBy(climate change, co2)`
- `affects(co2, climate)`

For transformations such as this to work, we need to have access to resources that support the claim that both of those logic statements are equivalent. If, for instance, a subject that defines the verb phrase "affectedBy" declares that its opposite verb is "affects"—and that other entities such as WordNet (Wordnet Website) (Miller, 1995) support the notion that *affects* and *affect* are different *senses* of the same word, then we are able to prove that both statements are equivalent.

Topic maps, in their original structure, model relations on a basis of roles. Cohere already applies role modeling as well. When we use simple predicates as mentioned above in the side note, and as used in both Compendium and Cohere, we are forced, on federation into a subject map, to either create specific relation types that honor those simple predicates and use documentation to allow determination of directionality in a relationship, or we must map simple predicates to bi-directional assertion types—as for instance mapping `causes` → `isCausedBy` to a generic `CausalRelationType`. When we do that mapping, we rely on the role types to specify which actor plays the *agent* role and which actor plays the *patient* (recipient of the causal action) role. For the time being, our implementation of TopicSpaces creates assertion types that retain the directionality implied by Compendium and Cohere relation types.

We begin to imagine a suite of *change listeners*. For instance, suppose we detect the difference `{co2, carbon dioxide}` and do not find evidence in the current map that those two terms are synonyms. Suppose further that at some later time, either the concept that carries the name "co2" is entered into the map, perhaps together with its synonym "carbon dioxide", or perhaps one or the other exists and a name is added. This would then enable a review of the merge situation. For the use case where simple name differences are noted but do not resolve, it might be worthwhile considering a *name change listener* that records a persistent interest in the terms detected. A generalized agent that listens for name changes could watch for terms of interest and fire an event notice at those agents interested. This might allow the IBIS system to re-evaluate its merge of the two given dialogue maps.

We follow the work of (Etzioni et al., 2007; 2008) in their *machine reading* projects, as demonstrated in the search engine TextRunner[20]. In the earliest expressions of that work, parsers were used to extract nouns, noun phrases, verbs, and verb phrases from text read on the Web. The nouns became *topics* and the verbs were used as *links* between topics. In that work, they discovered that an approach to *reading* as compared to traditional natural language processing is to create concept maps which can be mapped to *triples* which can then be used in question answering contexts. We believe that this approach to evolving tools for extending TopicSpaces and other sensemaking platforms into text harvesting and improving our ability to merge resources is appropriate to future research on this project. This is the concept behind our anticipatory conversation reader.

4.3 Platform Federation

We are engaged in projects to add value to existing and emerging IBIS conversation platforms along the following dimensions:

- Federation of existing platforms, for the time being restricted to Compendium, Debategraph, Cohere, and Deliberatorium
- Coupling Compendium to the Brahms agent platform
- Coupling IBIS conversations to the conceptual graph platform Cogitant

Each of these projects serves the purpose of continuously exploring the boundaries of the IBIS envelope; just how far can we push the evolution of boundary infrastructures necessary to support IBIS conversations? We are exploring opportunities to use agents along one dimension first: clouds of agents supporting query among IBIS conversation platforms. Eventually, in future work, the door will be opened to invite software agents into IBIS conversations as *domain experts* serving purposes such as finding answers to questions based on querying databases that otherwise are not available to IBIS conversations. We are also extending IBIS conversation representation into the realm of conceptual graphs.

4.3.1 Federating Existing IBIS Platforms—A Common IBIS Document Type

We have begun the task of collaboratively creating a serialization schema that will allow various IBIS conversation platforms to share IBIS conversations. Our initial focus is on the platforms Compendium, Cohere, Debategraph, and Deliberatorium. Our work is, at this writing, settling on a DTD (XML serialization Document Type Definition) based on a subset of the nodes defined in the Compendium DTD. We refer to serialized IBIS conversations as *documents.* While Cohere is

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

already capable of reading Compendium documents, it will need to acquire an export capability to, at the very least, serialize to the emerging common specification.

Debategraph and Deliberatorium each require the addition of export/import functions; that work is now in progress. The specification suggests that if any platform happens to export to nodes beyond the common specification, then those nodes can be ignored. Thus, Compendium can, according to the specification, export to the full Compendium DTD with the understanding that since the common DTD is a subset, other platforms will ignore content not specified or understood. This approach is based on the notion of semantic interoperability between the three (and other) platforms through a common file structure.

To facilitate the federation of IBIS conversations through a common schema, an IBIS Server has been constructed that can be reached through a trivial Web service API. That API allows an IBIS platform to submit a document, fetch an identified document, and fetch of list of available documents. The core functionality of this IBIS Server is defined to include those functions, but remain extensible for future work. As we mention below, some important "future" work is already taking shape in the form of the introduction of a different platform, Conceptual Graphs.

4.3.2 Coupling the Brahms Agent Platform to Compendium

A project that uses the Brahms agent environment (Sierhuis, 2008) offers an opportunity to explore coupling IBIS platforms together with an agent-based network as sketched in Figure 16 where `IC` is an instance of Compendium, and `A` is an instance of a Brahms agent.

Figure 16: Compendium-Brahms Agent Environment

We created a set of modifications to Compendium to add an agent adapter that permits Compendium users to perform queries on other Compendium databases. A query is a word or phrase plus *wildcard* symbols that enable queries to succeed on sentences that contain the query words plus others. For example, the query `%climate%` will succeed on sentence like "co2 affects climate". Any Compendium database that succeeds in finding nodes that respond to the query will return those nodes in a formatted JSON string to the agent network where they are returned to answer the query. The Compendium user then selects from among the nodes; those chosen are then imported into the user's IBIS map and linked to the node on which the query is based.

4.3.3 Coupling IBIS conversations to Cogitant—Conceptual Graphs

The paper (de Moor, et al., 2009) develops a case for the coupling of the *conceptual graphs* (Sowa, 1984) platform Cogitant[21] to IBIS conversations. We are proposing to do so by creating a Web-based converter that maps IBIS conversations to Cogitant's representation scheme.

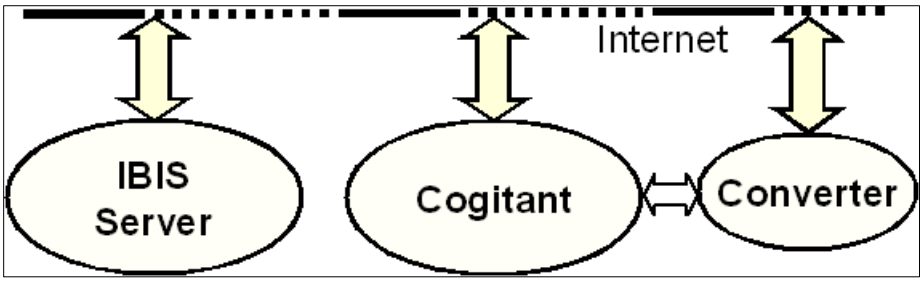

Figure 17: IBIS Server—Cogitant Conceptual Graph Engine

In the paper, we envision an architecture as illustrated in Figure 17, which engages the IBIS Server described above (§4.3.1), and extends the nature of queries available to IBIS conversations. From the paper (de Moor, et al., 2009):

> "Argumentation maps are visual representations of argumentation structures, making it possible to efficiently examine the cumulative results of protracted, distributed, and complex argumentation processes. Such visualizations can be useful to, for example, informally assess the status of public debates. Although the elicitation of argumentation maps is well supported, the support for the (1) analysis, (2) comparison, and (3) generation of maps relevant to particular stakeholders is still an open research problem. To develop such services, conceptual graph theory and tools can prove to be very useful."

4.4 Extending our TopicSpaces Architecture

Our research platform is intended to facilitate exploration of a sensemaking issue space much larger than IBIS conversations. Within the IBIS conversation space, but outside the scope of this research, we see room for further work. Our work thus far simply touches the surface of string matching, for instance. We see room for expanded research in that area. Further, the concept of merging subject representations, itself, opens the door to a much larger, cosmological study of ways in which knowledge representation systems can satisfy the larger picture of matching and representing subject identity. Those research areas relate to the internal structures and behaviors of a *device driver, a* back side that supports a universe of research related to user interface. Indeed, a *smarter* backside creates opportunities for innovation at the user interface.

4.4.1 Synonym Matching—Part of a Larger Subject Identity Issue

Yates and Etzioni (2009) argue that synonym resolution is critical to high-quality information extraction. We demonstrated a simplistic synonym detection system based on using a topic map

[21] Cogitant: http://cogitant.sourceforge.net/

that represents collections of names for concepts. That, alone, is just the tip of a deep iceberg, since below the surface of that demonstration lays a much larger set of issues related to detecting precisely which subjects are entailed in statements made during IBIS conversations. On the surface, synonym detection appears to be unworthy of great interest; the entire TextRunner inquiry, Web Information Extraction (WIE) as it is called, we argue, is clear evidence that subject identity remains a deep and important inquiry. Our claim is that the application of the topic mapping discipline provides a boundary infrastructure capable of supporting current and emerging research into the nature of representing and accurately recalling subjects entailed in IBIS conversations.

4.4.2 Opportunities to Explore New Modalities for Merging and Federation Architectures

We borrow and adapt a concept from the Ted Nelson *Xanadu* play book, his *virtual file* architecture (Nelson, 1999). The virtual file concept entails a large body of text created in a persistent way, and a *file* that is created as a document that contains a list of *links* into the large body of text (Figure 18). If some text is to be modified, new text is created at the end of the large body, and appropriate pointers in the virtual file are adjusted.

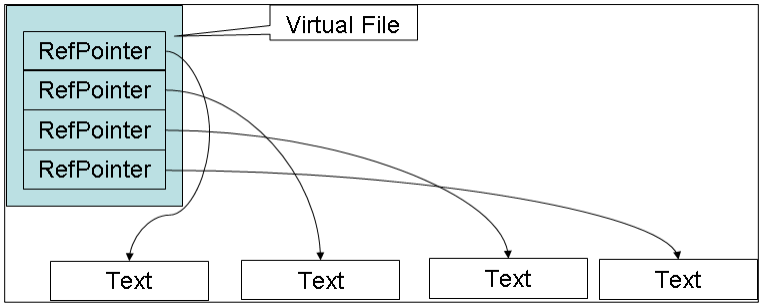

Figure 18: Virtual File System after (Nelson, 1999)

In the simplest expression of Nelson's virtual file concept, we imagine a *virtual proxy* that serves as a *binding point* for all merged proxies (Figure 19). In that scenario, one creates *merge assertions* (connections) that specify the nature of the merge. For instance, one proxy is designated the *original proxy* and another is designated a *merged proxy*; in each case, the *justifications* for the merge are presented in the merge assertions—rounded rectangles that connect each subject proxy to the virtual proxy. Since each merge assertion is, itself, a subject, each merge is thus a candidate for social intervention in a contested domain; each merge assertion is *contestable*. The virtual proxy itself gains a set union of *subject identity* properties from each merged proxy. This renders it as the core target for queries that seek subjects. When

timestamps are included in the merge assertions, one gains a *temporal* view of the history of a map-mediated subject.

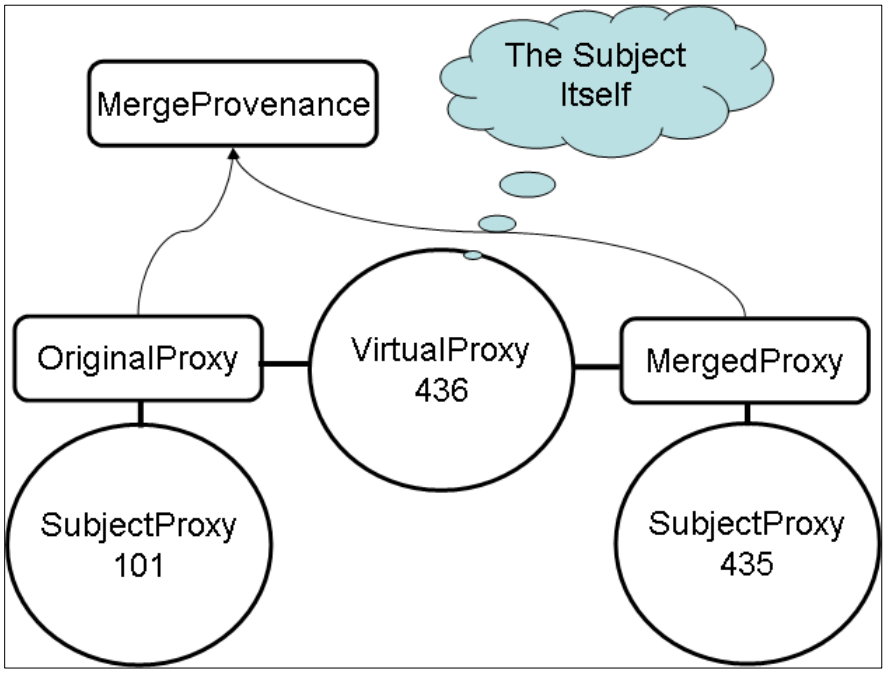

Figure 19: Virtual Merge (First Variant)

A first level advantage of the virtual proxy system is that the map then maintains strict separation of sources of world views as captured in each proxy. The alternative is to bind each and every element that enters into a proxy during a merge with the appropriate provenance information such that one can filter against particular sources where desired. By maintaining separation of sources, we are able to assert *specific identity* on different world views. For instance in Figure 19, we illustrate that we are able to identify the world according to a particular source in #101, and the same world according to a different source in #435. We observe a similarity at the conceptual level between virtual proxies and the Google Wave (Google, 2009), where a wave serves functions analogous to a virtual proxy.

A first level disadvantage of the virtual proxy system is that it can be viewed as an architecture that violates the *principle of co-location* associated with topic maps: one subject, one subject proxy. The virtual proxy system places the same burden of *joins* on the view system as does any relational database. A logical response to that objection is that the virtual proxy *is* the representation of the subject in question, and the fact that elements of that representation are dispersed elsewhere in the database is merely an implementation-level detail.

A novelty introduced into this new approach is the ability to merge *remote proxies* into a given map (Figure 20).

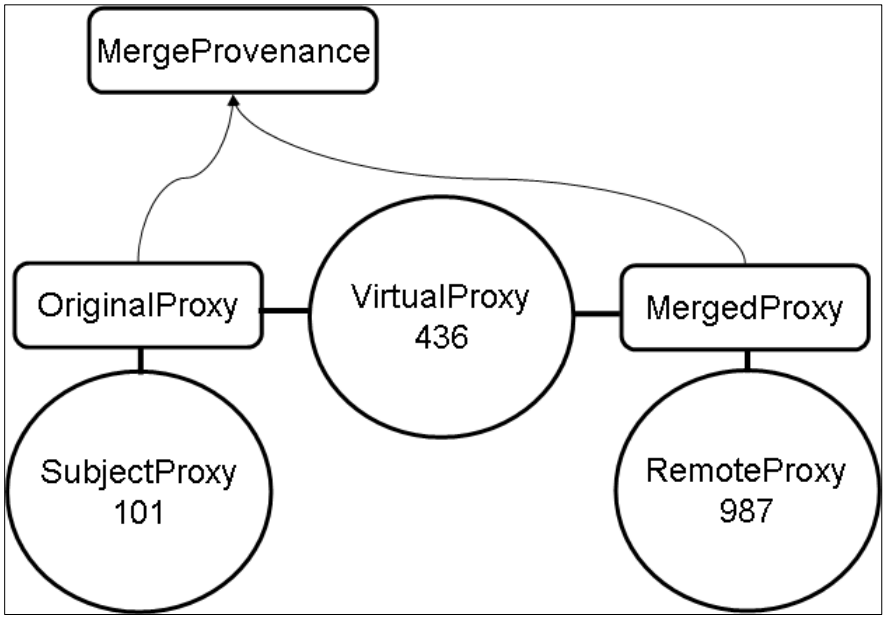

Figure 20: Merging a Remote Proxy

The ability to merge remote proxies means that one is maintaining a *hyper map*, a map that knows no bounds on the location of its proxies; proxies can exist, through Web services, anywhere on the Internet. This, too, is similar to the Google Wave platform.

We consider this new technology a candidate contribution of our research in the following sense. If one takes the time to study the entailments of machine-directed merging of subjects, one soon discovers the need to deal with post-merge objections raised by humans engaged with the machine. If one performs the usual *set-union* merge of proxies as performed by typical topic mapping engines, one is faced with the need to *unwind* a merge, a non-trivial exercise unless one has maintained sufficient audit trails of the merge. In the case of the virtual proxy, there is an *association* object, a subject proxy itself that links the virtual proxy with any merged proxies (Figure 20). That the merge is made by way of an association subject, that association subject can be the target of related IBIS conversations disputing or supporting the merge. We believe this architecture offers benefits to topic mapping since it opens all topic mapping behaviors—most notably, merging—to public audit and dispute.

Our contribution with this architecture is thus two new `SubjectProxy` types: `VirtualProxy` and `RemoteProxy`, plus a new assertion type: the `MergedProxyAssertionType`, which lays the foundation for wiring a relational graph that now includes merged subject representations. The `MergedProxyAssertionType` could potentially be used by humans to forge links with reasons given why humans believe a merge is appropriate. When a merge association is formed, it includes the rules that fired and voted both

in favor or against the merge; these explanations will assist humans in evaluating automated merges.

Consider this concrete example of a pair of IBIS conversations that, each, used the concept of `Thermohaline Circulation` as the subject of answer nodes, as illustrated in Figure 21.

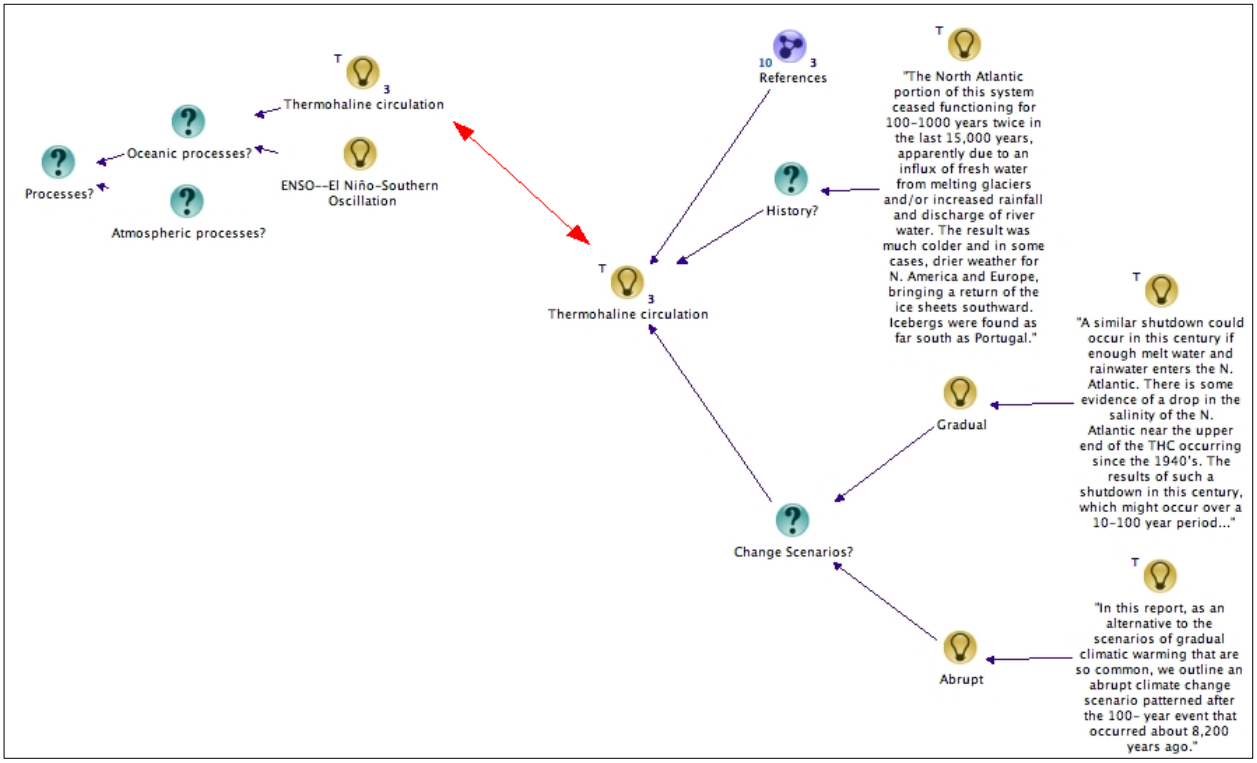

Figure 21: Two IBIS Conversations Using Same Subject

TopicSpaces detects the same-subject representations and performs a merge operation, as illustrated in Figure 22.

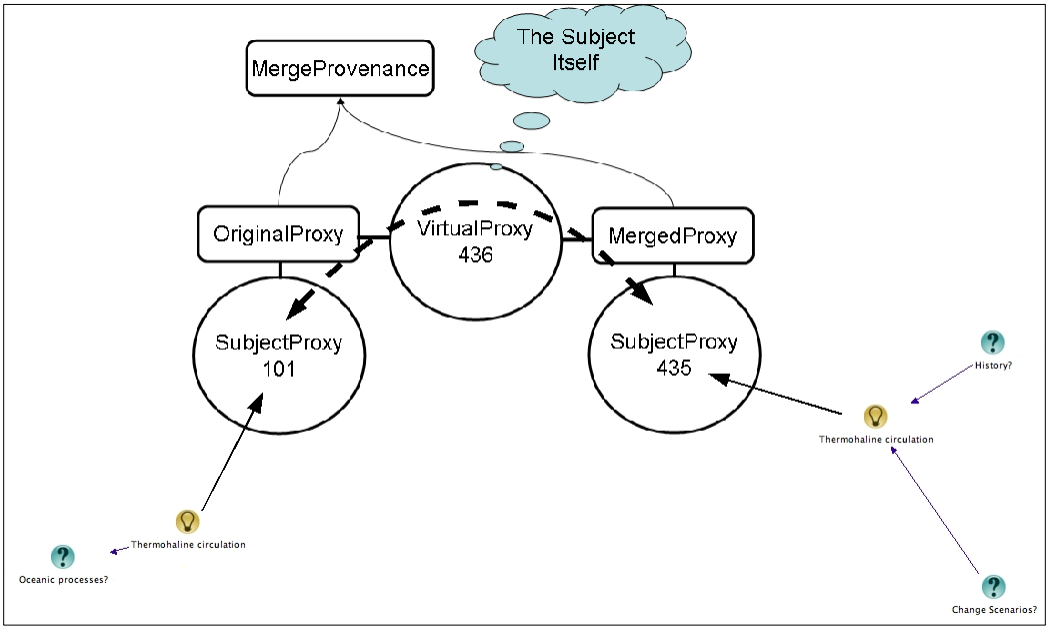

Figure 22: Virtual Merge of Two IBIS Conversation Nodes

Figure 22 show that each instance of an IBIS answer node remains independent of the other, preserving the natural contexts of each. `Proxy 101` is the IBIS node on the left, and `Proxy 435` is the IBIS node on the right. Still, each becomes linked to the other through the context of a `VirtualProxy` which represents the subject that carries the name *Thermohaline Circulation*. That same `VirtualProxy` would similarly link other SubjectProxies in the map that represent the same subject. Linking in a similar way, all such IBIS nodes would be federated through this process.

4.4.3 Compendium's Advanced Features

Compendium includes two features that are of enormous value to mapping, which, if available to other platforms, would improve our ability to federate IBIS conversations. They are:

- Transclusion, a term coined by Ted Nelson—the ability to re-use one IBIS node many places in one or many maps. Transclusion is based on the fact that all Compendium nodes are present in the same database. Transclusion across different Compendium installations is not supported, though the IBIS-agent federation project described above (§4.3.2) may make that available when Compendium is running in an agent-based network.
- Tags—Compendium supports *tagging*, where a selected node can be annotated with tags created elsewhere. Figure 23 is a composite illustration showing a selected node from a map and the tag associated with it. That tag can be used elsewhere to indicate that "Thermohaline circulation" is a subject referenced in the tagged node. That node is viewed from Appendix A, Map 7, a *Topics* map.

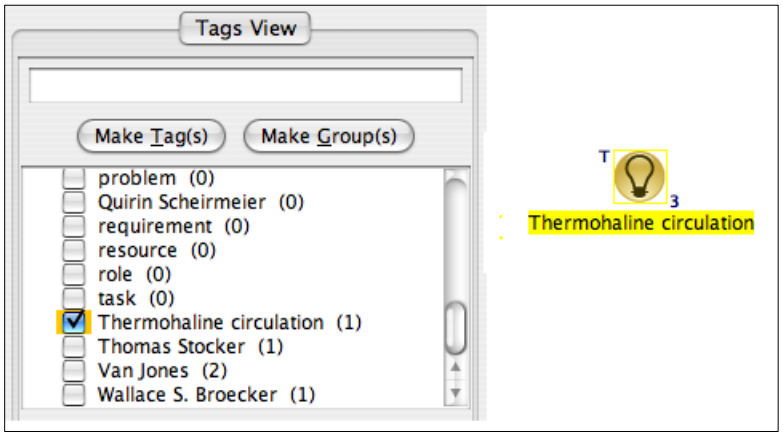

Figure 23: Selected Compendium Node and its Tags

In our discussion about merging, we identified an important issue: knowing which *subjects* are entailed in IBIS statements made in IBIS nodes. If a node is transcluded and used elsewhere, say,

in a different conversation, then *sameness* is guaranteed. For example, consider Appendix A, Map 3, and also consider Appendix A, Map 8. Notice the node that carries the statement "Thermohaline circulation" has a small "3", which means that node is used three times, and both instances are now in view. Should we wish to merge Map 8 into Map 3, the decision to make the merge based on that particular node is a simple one.

While considering Map 8, notice that there are nodes with a small "T" nearby. That indicates that there are tags associated with those nodes with a "T". In the case of the node that responds to the question "History?", the tag associates that node with the reference for its citation. Other tags could similarly associate that node with "North Atlantic", "fresh water", "melting glaciers"—which, it might turn out, is modeled as a subclass of "glaciers", which means the subject "glaciers" is entailed with that node as well.

How might that opportunity be facilitated? Consider an IBIS map that is created specifically to capture *topics,* as for example Appendix A, Map 8. In that map, we might create an answer node for "North Atlantic", and create a tag with that name string, attached to that node. Then, anytime some new node is created that includes the "North Atlantic" subject in its statement, that tag can be selected. Map 6 is doing the same thing for references.

If we extend this vision and include the ability to network IBIS platforms, then a single location for topics and references can be established, from which each new conversation can transclude nodes or borrow tags. That installation would be called a topic map. Thus, the notion of enabling conversations among IBIS platforms to share resources that are organized according to topics facilitates easier federation of disparate conversations. We have introduced networked re-usability to IBIS nodes and tags.

4.5 Relation to Other Work

The core of this work lies in the evolution and demonstration of a federation platform. A closely related open source platform is the Apache Solr project, which is described at its website[22] as follows:

> "Solr is an open source enterprise search server based on the Lucene Java search library, with XML/HTTP and JSON APIs, hit highlighting, faceted search, caching, replication, a web administration interface and many more features. It runs in a Java servlet container such as Tomcat. "

We draw the following comparisons between Solr and TopicSpaces based on further details of Solr's architecture. Solr uses the Lucene full-text indexing engine as a basis for its persistence

[22] Solr: http://lucene.apache.org/solr/

and knowledge organization. TopicSpaces uses a topic map engine as a basis for its persistence and knowledge organization. Both platforms facilitate finding resources against keywords; Lucene organizes resources according to documents in which terms are found, as does the index at the back of a book, whereas a topic map creates the equivalent of a "document" in the form of a SubjectProxy, and gathers representations of resources inside appropriate proxies. The end result is the same; resources organized in a particular fashion. Solr defines the documents to use for organization using author-defined *schema definitions*; TopicSpaces uses author-defined *legends* to perform the same task. If a Solr author wishes to persist information resources for, say, cameras, then a schema is defined that includes necessary keyword classes, such as shutter speed, weight, price, and so forth; in TopicSpaces, a legend would be created with the same or similar definitions.

We note, with acknowledged appreciation for the wide-ranging and thoughtful accomplishments of contributors to the many open source projects hosted by the Apache Foundation, that an entirely reasonable implementation of our research project could be accomplished using Solr coupled with schema definitions that are entailed in IBIS conversations. We add, however, that our long term intentions for this research extend beyond IBIS conversations, and that extending Solr documents into the realm of capturing representations of roles and relations will require more research. Our research is presently predicated on lessons learned from the implementation of a variety of topic map platforms.

5.0 Research Plan

Once we start to federate structured conversations, what looms like large variation to us as individuals, smooths out; that perhaps is the only way we can actually have conversations on meaningful topics engaging varieties of subjects. There is no *per se* limit on the complexity of subjects or the subjects that compose them; while structural and behavioral patterns serve to tame the space of federation issues, we expect that our literature review has not uncovered all the necessary dimensions.

Our research plan covers four phases: platform implementation, field work, concurrent software evolution, and write up. To date, we report the following progress in support of this research:

- **IBIS Portal Dev**: Prototype TopicSpaces has been installed and exercised by a few individuals using its built-in IBIS platform, its built in blogging and social bookmarking features, and its help and feedback systems.
- Conducted unit tests of the TopicSpaces merge rules to perform the work described

above (§4.2.4) on trivial examples of merging as a means to verify that a rule-based merge engine can be implemented

- Common Format: Created a draft common IBIS serialization format related to (§4.3.1). The DTD for that format is a subset of the DTD used by Compendium
- IBIS Server[23]: Created a prototype Web server to persist IBIS conversations in the common serialization format. Server has been delivered to The Open University and is in the process of being installed for use in sharing IBIS documents.

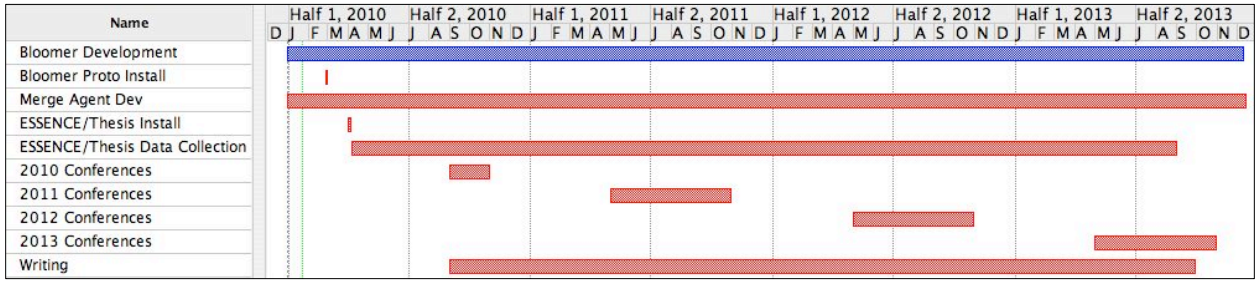

Figure 24: Project Timeline

Figure 24 is a timeline chart that anticipates a four year period beginning end of December, 2009 and ending around the first of September, 2013, when our dissertation will have been written, ready to defend.

5.1 Platform Implementation

We continue to evolve the TopicSpaces platform. The platform we are building is the open source Bloomer[24] project, which, as mentioned earlier, will be delivered to Gimcheon, South Korea early in 2010. Bloomer is a MediaWiki-based[25] collaboration platform with new extensions to add IBIS conversations and connection to the TopicSpaces federation server. Our specific plans for Bloomer include installing a public test platform local to Palo Alto, California before March, 2010 in anticipation of a mid April delivery to South Korea. A non-public instance of Bloomer exists as this is written (December, 2009) and significant progress suggests that the end-of-February milestone for a public version will occur on time. We illustrate the timeline for Bloomer development in Figure 22 as continuous. We show installation of the ESSENCE/Thesis platform as occurring early in April, 2010. The first public development version of Bloomer is to be installed at the end of February, 2010 for local and experimental use.

[23] IBIS Server: http://ibisserver.open.ac.uk/
[24] Bloomer project: http://code.google.com/p/bloomer/
[25] MediaWiki: http://www.mediawiki.org/wiki/MediaWiki

5.2 Field Work

This phase entails installation and evaluation, all based on the Bloomer project.

In addition to the Millennium Project's Gimcheon installation, we plan to install TopicSpaces and engage ESSENCE[26] participants. As mentioned below in 6.4, there are other Millennium Project sites expected to take delivery, installation, and training related to Bloomer.

Field work provides an opportunity to, at once, monitor the performance of our merge technology, and to explore the ability to encourage (through user interface controls) the ability to suggest merges where humans detect opportunities. At the same time, we plan to observe, record, and to otherwise explore those patterns associated with the use of our technology and social characteristics behind those patterns. For example, in (§2.0) we examined a case where deliberations led to extremism and reduction of diversity. We suggested that an experiment could be conducted to explore and characterize the nature of deliberations. Such an experiment is imagined to be conducted through a modified IBIS interface that does not publish responses to the users; one such elicitation is conducted prior to a public elicitation, then following. We propose this as a generalized class of experiments rather than a particular experiment; at this writing, we lack sufficient experience with large-scale IBIS conversations with which to make concrete proposals.

As described below, we plan to continuously evaluate, through questionnaires, user feedback to determine the validity of our thesis, and to discover un-anticipated issues related to the evolution of our merging system. Field work is illustrated in Figure 24 as beginning following the ESSENCE/Thesis Bloomer installation, and continuing

5.3 Concurrent Software Evolution and Research

We described a hybrid system in which TopicSpaces will attempt to perform automated merges where obvious, suggest merges to be made where there is some but insufficient reason to perform the merge, and will honor merges that are suggested by conversation participants. To facilitate the evolution and testing of those capabilities, we propose to create a range of focused test cases around important topics from climate change. These test cases each engage increasing complexity in the merge problem to solve. Test cases can be derived through combinations of hand-picked cases from live conversations, and from made-up cases as described above (§4.2.4). Test cases will explore the detection and utilization of structure in the conversation with a goal to derive heuristics available to the system based on detected structure. Merge system development

[26] ESSENCE website: http://events.kmi.open.ac.uk/essence/

is expected to be conducted concurrently with TopicSpaces/Bloomer evolution. During this activity, background evolution of the merge agent continues. A body of code exists with which to create early trials as mentioned; a body of code towards a prototype anticipatory conversation reader above (§2.3.6) is available to probe that avenue of research. This aspect of our work is modeled in Figure 24 as Merge Agent Dev, which is continuous during the entire Bloomer development cycle.

Our literature review uncovered the notion of anticipatory systems; anticipatory behavior, the ability to anticipate and react according to those expectations is core to any complex adaptive system. We sketched an artifact—anticipatory conversation reader—and have suggested that there are open source components available to us for explorations along that line of inquiry. We believe that something like an anticipatory conversation reader will be required to make significant progress in structured conversation federation, but the level of unknowns in relation to that inquiry remain unclear to us at this time, with the exception that existing projects mentioned in our review suggest the ability to create an artifact that will allow us to test and evolve such ideas.

Given that the field of subject-centric computing is an emerging and rapidly growing discipline, we expect to continue our background research and design efforts, and to report on progress at important conferences, two of which are representative of our direct efforts:

- Topic Maps Research and Applications (TMRA)—held in Leipzig Germany, in October
- Knowledge Federation Conference—held in Dubrovnik, Croatia, following TMRA

Related conferences include those associated with online discourse, computational linguistics, and scientific discourse.

5.4 Write up

Write and defend a dissertation. As a process, we expect writing to be conducted concurrently with all phases of this activity, to be assembled later into a final document. This work includes contributions or technical papers to several conferences over the course of the coming years.

In each calendar year including 2010, we anticipate conferences related to topic mapping (Leipzig) and knowledge federation (Dubrovnik). We are, at this writing, beyond appropriate submission dates for the varieties of Web and related conferences, but expect to contribute to those beginning in 2011. We propose to create and chair at least one conference on the state of online deliberation, perhaps early in 2011. Ideally, a conference specific to hypermedia discourse in its many ramifications is in order. Blocks of time are allocated in Figure 24 for each year of

this project going forward for purposes of paper submission and conference attendance.

Our writing includes results of continuous literature review, conference presentations, and experimental results. Actual dissertation write up is modeled in Figure 24 to begin with our first conference contributions; conference papers are to be treated as candidate elements of the final dissertation. We do not discount the notion that sufficient progress could be made early in the timeline such that end points could be moved sooner than modeled.

6.0 Risks

We identify the following risks associated with our research and talk about ways to mitigate them.

6.1 Technical

Conversations are so complex that, even given the contributions of structure and background domain knowledge available to our research platform, we identify a risk that IBIS conversations cannot be federated to any degree greater than trivial automated detection and the occasional suggestions by participants. Our goal is to create a boundary infrastructure capable of evolution through further research; we acknowledge the risks associated with the possibility that technology will not advance to the degree that we will be able to claim federation success to any degree greater than the trivial merges we have already demonstrated. The essence of this work is to define a pattern language that, itself, defines a human-computer ecosystem for IBIS conversations. To validate that pattern language, we do not need to federate all IBIS conversations or even every IBIS conversation that could be shown by someone to be capable of being federated. We see our task as that of evolving the pattern language and its expression in an implementation in the form of a boundary facility that is capable of further evolution. Our stopping rule is one of demonstrating the ability to merge statements of a more complex linguistic form as we sketched in our research report, and showing that we have a platform capable of supporting further evolution on more-complex linguistic forms for IBIS statements.

Our platform will be installed in world-class situations which are capable of yielding large collections of possibly difficult conversations on which to access merging performance. We anticipate mitigation of this risk through controlled conversations we will engage on our own installation, and through the use of templates to further constrain those conversations to manageable, perhaps increasingly complex conversation patterns. Still, we expect to learn from the conversations created elsewhere.

Another risk is failure of the participant pool to accept structured conversations as a core means of sensemaking. There is some evidence that this risk is being mitigated by means of the Debategraph exposure as mentioned earlier. What remains to be seen is the relative contributions made by the public as compared to those made by David Price. Still, we believe that emerging events are on our side. Simply stated, if a sufficient population of participants is unwilling to engage in IBIS conversations related to a meaningful contested domain, then we will have nothing to work with. This risk is somewhat mitigated since we are already tasked to work with others to create a collection of climate-change-related IBIS conversations in support of the ESSENCE project. It is our intent to generate at least a small body of resources on which to proceed with this research.

6.2 Operational

There exists the risk of not of completing a prototype IBIS platform. This short-term risk has been mitigated due to funded research that requires the services of our boundary infrastructure platform, the Bloomer project as mentioned above. The codebase for TopicSpaces is based on several generations of TopicSpaces prototypes that have been used in small trials online in the past.

6.3 Geographic

This project entails installations in geographic locations distant from our primary location. In the case of the South Korean installation, the contract calls for travel to the location for installation and training. Subsequent interactions with users can be handled directly within the collaboration portal, and through electronic communications such as Skype. The geographic distance between this author and the thesis committee has, thus far, not surfaced as a particular issue.

6.4 Time and Finance

The current employment situation has resolved, for the next year at least, to contracts related to delivery of Bloomer projects. The South Korea project is funded; a second instance of the same platform is scheduled to begin funding in February, 2010 for delivery to another Asian country, and a third instance is scheduled for March, 2010 for delivery in another country. Time is available in that schedule to continue the thesis research since delivery of Bloomer products relates directly to the thesis project. Finance beyond 2010 is, at the moment, an unknown quantity. We believe that success of the installations in 2010 will yield further contracts in later years.

6.5 Resources

The project has all the resources it needs to continue prototype development and installations.

6.6 Legal and Political

Climate change is a wicked, political issue, but that does not affect this research; if anything that situation enhances our ability to probe and study the effects of introducing IBIS conversations to a wider audience. Legal issues might relate to online users in the same sense as Wikipedia has experienced lawsuits; in our case, the projects are installed through the Millennium Project which takes the lead in all project responsibilities. We still may eventually seek legal advice in such matters.

7.0 Evaluation

We begin with the premise that user feedback forms will generate some hints and suggestions for improvements in both the user interface made available to users and to the usability of the platform itself. Geoffrey Bowker (2009, personal communication) has pointed out a weakness in general feedback forms, and suggests targeted feedback conversations around specific situations. Our own instincts are to provide affordances for both; general feedback forms should be maintained in order to present, as suggested in the book *Cluetrain Manifesto* (Levine et al., 1999), a visible and continuous conversation with users; providing for occasional scheduled feedback conversations around specific situations is to be included in this research. This approach is suggested, for instance, after a particular conversation is concluded and target feedback questions are used to determine what worked and what did not work and open the door for further ideas from those users.

We further expect to create and/or attend periodic meetings with prime user communities to better understand the platform's capabilities, needs, and generate "mid-course corrections" as needed—all part of the evolutionary processes on which this research is based. This is seen as somewhat different from activity-specific feedback mentioned above. This activity, as we presently see it, is, quite literally, as *face-to-face* as possible, as we are discussing already with one of our Asian clients.

Our research is about federation of discourse. Evaluation of federation entails the conduct of controlled trials, each trial more complex than the earlier trial. This creates opportunities to evolve and evaluate the extensible nature of the merging platform. During these trials, we systematically vary parameters; we are able to learn and document what is easy, what is hard,

and where further research is necessary. Clara Mancini (2009, personal communication) has suggested the opportunity to run trials where communities of practice are asked to make merge suggestions and compare those to the system's recommendations. In some sense, that aspect is already planned into the platform since users will have the ability to mark objects for potential merge, and to document their reasons for the suggestions.

Finally, as we have suggested, one of the expectations of subject-centric computing is that we should not, as platform users, be required to navigate to many different places to view all that is known about a particular subject. The mechanisms that facilitate subject-centric computing are described as merge operations. Merge operations, in a fashion analogous to language translation, will be deemed successful if and only if all platform users agree with the merge; we do not see *success* in terms of black-white, yes-no, binary events. In fact, a precise measurement of success remains to be discovered.

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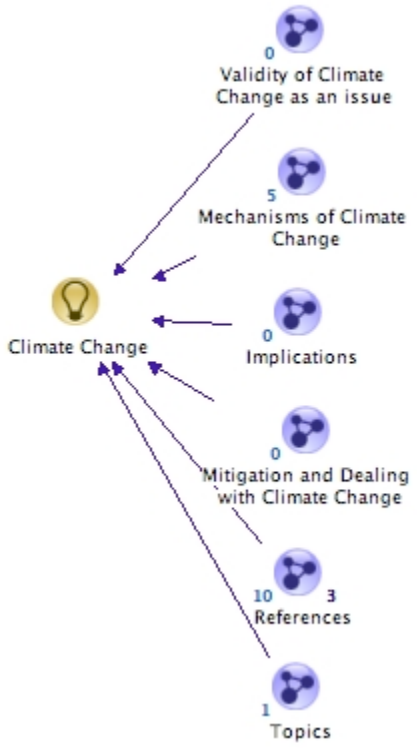
Appendix A—Climate Issue Maps

Shell IBIS conversations created to explore the space of IBIS federation in the context of ESSENCE (climate change). It is expected that these issue maps will evolve as research progresses.

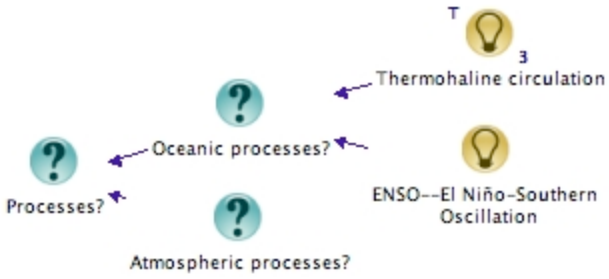
Map 1 Climate Change Top-level



Map 2 Validity of Climate Change as an Issue

<TBD>

Map 3 Climate Change Mechanisms



Map 4 Climate Change Implications

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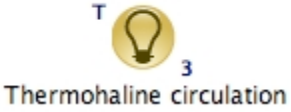
Map 5 Climate Change Mitigation and Dealing

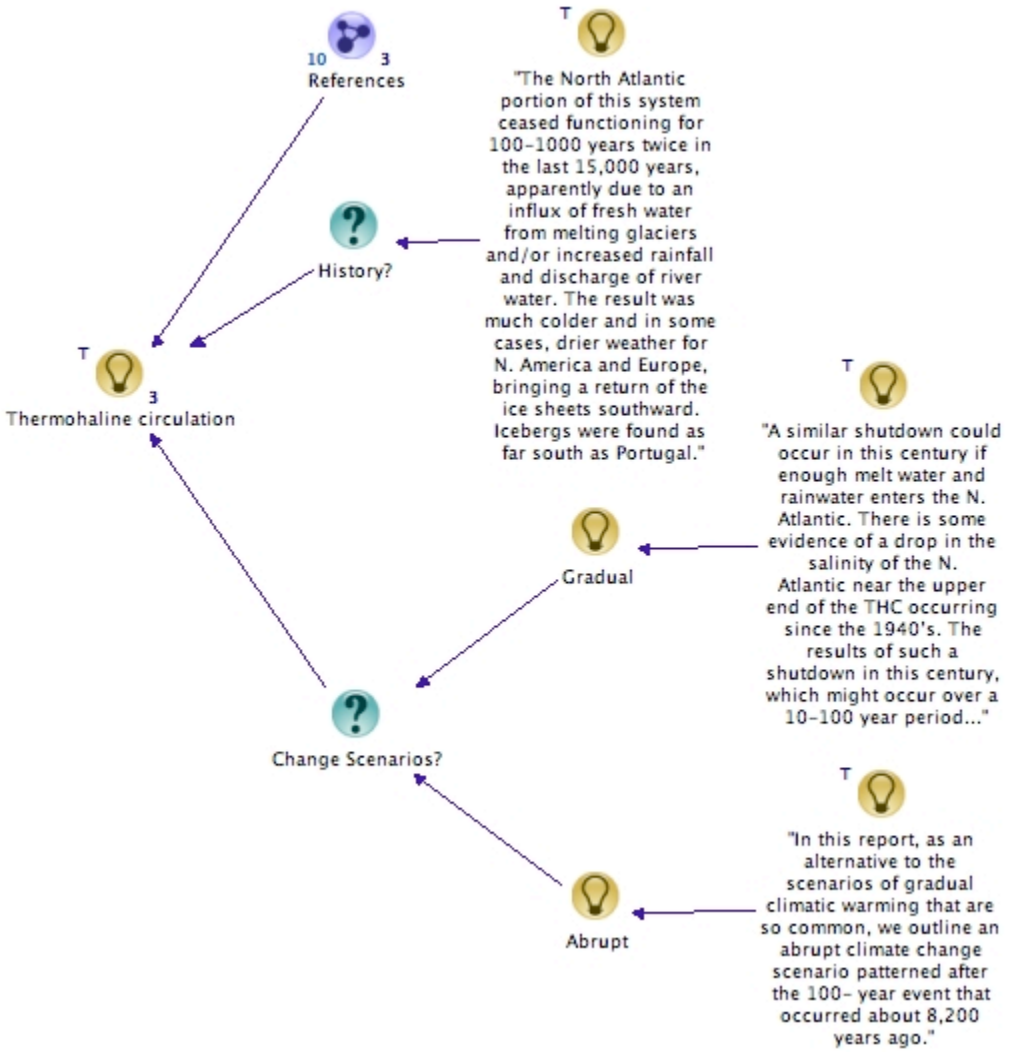
<TBD>

Map 6 References

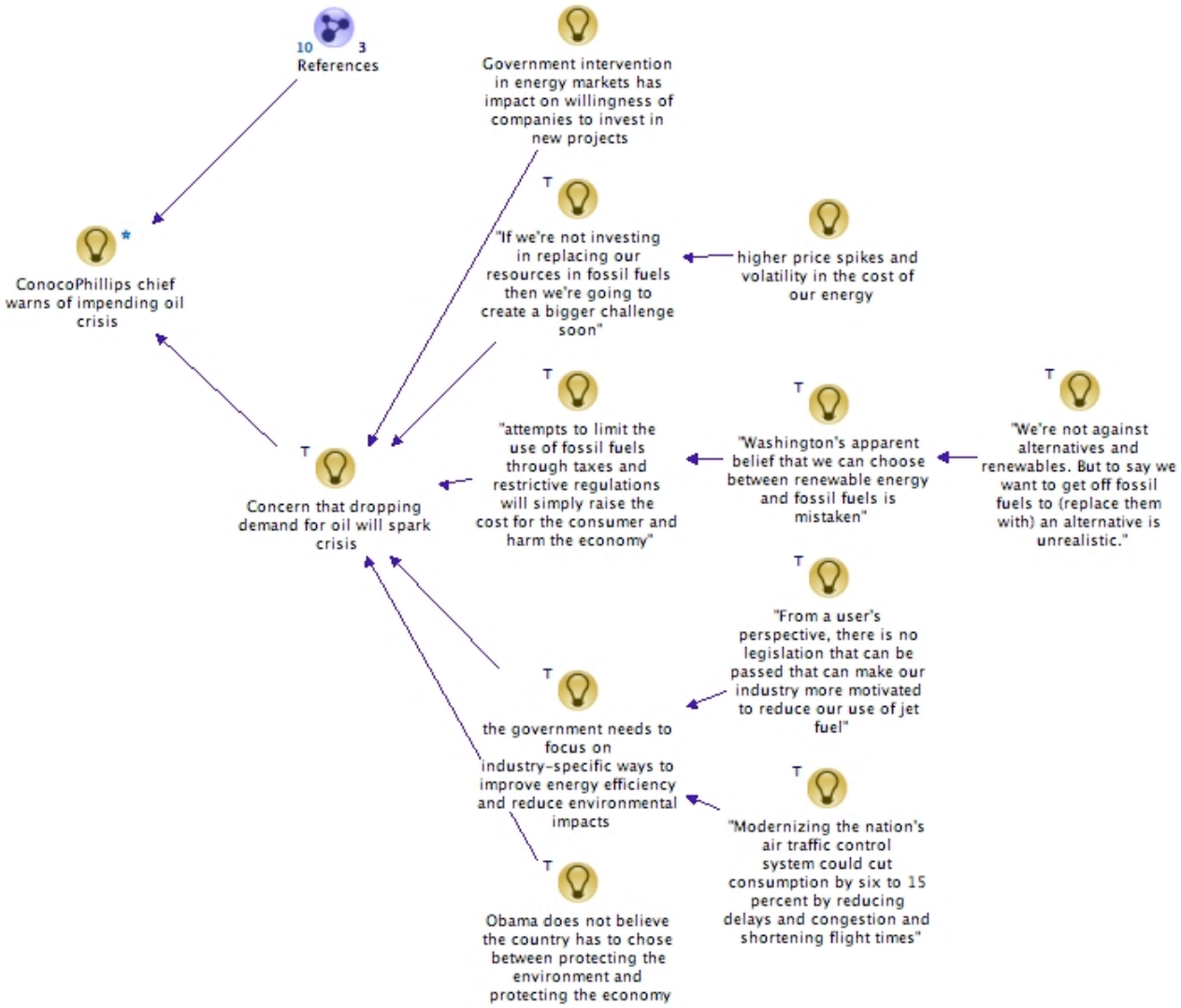
Map 7 Topics



Map 8 Thermohaline Circulation



Map 9 Oil Crisis 1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References
ConocoPhillips chief warns of impending oil crisis
Government intervention in energy markets has impact on willingness of companies to invest in new projects
"If we're not investing in replacing our resources in fossil fuels then we're going to create a bigger challenge soon"
higher price spikes and volatility in the cost of our energy
Concern that dropping demand for oil will spark crisis
"attempts to limit the use of fossil fuels through taxes and restrictive regulations will simply raise the cost for the consumer and harm the economy"
"Washington's apparent belief that we can choose between renewable energy and fossil fuels is mistaken"
"We're not against alternatives and renewables. But to say we want to get off fossil fuels to (replace them with) an alternative is unrealistic."
"From a user's perspective, there is no legislation that can be passed that can make our industry more motivated to reduce our use of jet fuel"
the government needs to focus on industry-specific ways to improve energy efficiency and reduce environmental impacts
"Modernizing the nation's air traffic control system could cut consumption by six to 15 percent by reducing delays and congestion and shortening flight times"
Obama does not believe the country has to chose between protecting the environment and protecting the economy