Contested Collective Intelligence: Rationale, Technologies, and a Human-Machine Annotation Study

Article *in* Computer Supported Cooperative Work · October 2011

DOI: 10.1007/s10606-011-9155-x

3 authors:

Anna De Liddo
The Open University (UK)

Agnes Sandor
Naverlabs Europe

Simon Buckingham Shum
University of Technology Sydney

Contested Collective Intelligence: rationale, technologies, and a human-machine annotation study

Journal Article

De Liddo, A., Sándor, Á. and Buckingham Shum, S. (2012). Contested Collective Intelligence: Rationale, Technologies, and a Human-Machine Annotation Study. *Computer Supported Cooperative Work.* DOI: 10.1007/s10606-011-9155-x

The final publication is available at www.springerlink.com

Contested Collective Intelligence:

Rationale, Technologies, and a Human-Machine Annotation Study

Anna De Liddo[1], Ágnes Sándor[2] & Simon Buckingham Shum[1]

[1] Knowledge Media Institute, The Open University, Walton Hall, MK7 6AA, Milton Keynes, UK (Phone: +44-1908-653591; Fax: +44-1908-653169; E-mail: a.deliddo@open.ac.uk; Phone: +441908-653591; Fax: +44-1908-653169; E-mail: s.buckingham.shum@open.ac.uk);

[2] Xerox Research Centre Europe, 6 chemin Maupertuis, F-38240 Meylan, France (Phone: +33-476615014; Fax: +33-476615099; E-mail: agnes.sandor@xrce.xerox.com)

Abstract. We propose the concept of *Contested Collective Intelligence (CCI)* as a distinctive subset of the broader Collective Intelligence design space. CCI is relevant to the many organizational contexts in which it is important to work with contested knowledge, for instance, due to different intellectual traditions, competing organizational objectives, information overload or ambiguous environmental signals. The CCI challenge is to design sociotechnical infrastructures to augment such organizational capability. Since documents are often the starting points for contested discourse, and discourse markers provide a powerful cue to the presence of claims, contrasting ideas and argumentation, discourse and rhetoric provide an annotation focus in our approach to CCI. Research in sensemaking, computer-supported discourse and rhetorical text analysis motivate a conceptual framework for the combined human and machine annotation of texts with this specific focus. This conception is explored through two tools: a social-semantic web application for human annotation and knowledge mapping (Cohere), plus the discourse analysis component in a textual analysis software tool (Xerox Incremental Parser: XIP). As a step towards an integrated platform, we report a case study in which a document corpus underwent independent human and machine analysis, providing quantitative and qualitative insight into their respective contributions. A promising finding is that significant contributions were signalled by authors via explicit rhetorical moves, which both human analysts and XIP could readily identify. Since working with contested knowledge is at the heart of CCI, the evidence that automatic detection of contrasting ideas in texts is possible through rhetorical discourse analysis is progress towards the effective use of automatic discourse analysis in the CCI framework.

Keywords: collective intelligence, discourse, human annotation, knowledge mapping, machine annotation, learning, sensemaking, network visualization, social software, social annotation

Contents

1. Introduction 2
2. The concept of contested collective intelligence 3
3. Enabling reflective social discourse through annotation 7
4. Human and machine discourse-centric annotation technologies 9
5. Cohere: discourse-centric human annotation 13
6. XIP: cohere: discourse-centric machine annotation 17
7. Case study: integration of human + machine annotation 19
8. Comparison of human and machine annotations 24
9. Discussion and future work 28
References 32

1. Introduction

In this paper we argue that *Contested Collective Intelligence (CCI)* should be seen as an important and distinctive subset of Collective Intelligence (CI). CCI is conceived as an emergent capability which depends on being able to pool and connect people's interpretations, comments and debates around issues, often anchored in diverse documents. CCI is relevant to the many organizational contexts in which it is important to work with contested knowledge, for instance, due to different intellectual traditions, competing organizational objectives, information overload or ambiguous environmental signals. The CCI challenge is to design sociotechnical infrastructures to augment such organizational capability. To cope with such dilemmas, we will argue that organizations need ways to construct plausible, possibly competing, narratives. This motivates the design of a CCI platform that mediates, captures and structures contributions that may be in tension. For this reason, we see discourse, signaled in texts by distinctive rhetorical moves, as providing a CCI infrastructure with important cues to relevant phenomena.

This paper extends the initial CCI proposal by De Liddo and Buckingham Shum (2010) with a more detailed presentation of the concept, a conceptual framework attending specifically to the role of document annotation, the addition of automated annotation technology, and a case study evaluating combined human/machine corpus analysis. The paper is structured as follows: Section 2 defines CCI conceptually, building on research in sensemaking and computer-supported discourse. We then propose a framework that builds on the combination of human and machine document annotation in order to structure reflective social discourse and develop the CCI concept (Section 3). We specify the technological components of a software platform to support the development of CCI through structuring discourse and document annotation (Section 4). We present Cohere (Section 5) and XIP (Section 6), as exemplars of discourse-centric tools for human and machine annotation, and propose them as prototype components of a CCI platform. We then describe a case study of the combined use of Cohere and XIP in a sensemaking field trial (Section 7). The first results are obtained by a comparison of human and machine annotation of a set of project reports, which provide quantitative and qualitative insight into their respective contributions (Section 8). We conclude by considering our contribution to some of the broader questions around organisational CI, and identify open challenges for realizing CCI infrastructures (Section 9).

2. The concept of contested collective intelligence

Research into Collective Intelligence seeks to develop the conceptual foundations, and sociotechnical infrastructures, which will increase our capability to make sense of complex problems specifically by combining contributions from many sources. Informatics CI research focuses on the distinctive contributions and opportunities that the digital medium offers when woven into human practices. An important challenge for the field is to devise appropriate dimensions, so that we can meaningfully position different notions of CI in relation to each other.

We focus on *contested* CI as an important and distinctive topic based on the uncontroversial observation that phenomena such as divergent perspectives, inconsistencies, ambiguity and explicit disagreement pervade organizational life. In well-understood problem spaces, there is an objectively optimal or correct response, even if this is only apparent in hindsight. In many other contexts, however, such as horizon scanning, intelligence analysis or public policy formulation, there will almost always be contention over the right answer, and indeed, over how to frame the problem and success criteria (Rittel and Webber 1973). In organizational life, different intellectual traditions (both academic and professional), or competing organizational objectives (e.g. different teams with divergent priorities) invariably set up debates of different sorts. (These may, of course, be positive or negative depending on the tone of the discourse, which online channels can exacerbate when used without care, but we aim to show in this paper how CCI tools can draw attention to substantive discourse moves within texts and through analysts' annotations.)

However, in addition to the worthy challenge of promoting more critical, rational analysis and discourse, we see an important motivation for CCI from research into sensemaking. Sensemaking has emerged as a definable research field over the last 30 years, dating back to Doug Engelbart's visionary 1960s work on the need for tools to "augment human intellect" in tackling "complex, urgent problems", Horst Rittel's formative work in the 1970s on "wicked problems" (see Buckingham Shum 2003, for a review), and Brenda Dervin's work within communication studies (Dervin and Naumer 2009). As noted in the call for a recent journal issue devoted to the subject (Pirolli and Russell 2008), influential work has also "emerged quasi-independently in the fields of human-computer interaction (Russell et al. 1993), organizational science (Weick 1995), and cognitive science (Klein et al. 2006)." See Selvin (2011, forthcoming) for a detailed review of the sensemaking literature from a human-centred computing perspective.

We start with Karl Weick (1995), who argued that sensemaking is literally "the *making* of *sense*", i.e. *giving form to interpretations* (cf. the specific focus on sensemaking representations by Russell et al. 1993). Weick (1995, p.6) proposes that, "Sensemaking is about such things as placement of items into frameworks, comprehending, redressing surprise, constructing meaning, interacting in pursuit of mutual understanding, and patterning." Extensive research into the interplay of cognition and external representations (e.g. Scaife and Rogers 1996), confirms that the very process of externalizing thought shapes unfolding understanding, from attempting to verbalize inchoate thoughts, to sketching diagrams, to codification in structured symbol systems.

Other research in sensemaking emphasises that when confronted by complex dilemmas, personal and collective intelligence is rarely displayed through rapid categorization of the problem and solution, the hallmarks of expert performance in well-understood problem spaces. The work of Snowden and colleagues (e.g. Kurtz and Snowden 2003; Snowden and Boone 2007) is one approach to bringing together sensemaking and strategic thinking, in which they distinguish what they term *known, knowable, complex* and *chaotic* problem spaces. Together with Weick (e.g. Weick 2006, on the systemic missing of child abuse symptoms until the 1950s), these authors highlight the dangers of entrained thinking, in which experts fail to recognise a novel phenomenon and categorise it based on prior expectations. They call for sensemaking-support systems which draw attention to exceptions, and ensure that one remains open to a multiplicity of perspectives for as long as possible.

For Weick, sensemaking is inextricably tied to social context:

> "The point we want to make here is that sensemaking is about plausibility, coherence, and reasonableness. Sensemaking is about accounts that are socially acceptable and credible. […] It would be nice if these accounts were also accurate. But in an equivocal, postmodern world, infused with the politics of interpretation and conflicting interests and inhabited by people with multiple shifting identities, an obsession with accuracy seems fruitless, and not of much practical help, either." (Weick 1995, p.61)

The CCI challenge may thus be framed as one of creating infrastructures capable of *gathering, externalizing* and *socially validating* accounts about past, present and future worlds, in order to establish "plausibility, coherence, and reasonableness". Such accounts are narratives, and Browning and Boudès (2005) provide a helpful review of the similarities and differences between Snowden's and Wieck's work on sensemaking, with particular emphasis on the centrality that narrative plays in their proposals for how we manage complexity.

Clearly, such narratives have always been woven within and across conventional organizational documents and interpersonal interactions, but more recently, these have been extended and made more visible in digital archives and social media channels, opening the new opportunities for computational support. However, while current platforms can provide useful but relatively simple quantitative analytics (e.g. user traffic flow, term-based similarity, emerging topics, online participation levels, social networks), they provide fewer clues to qualitative, higher order constructs of the sort that we envisage CCI providing as additional metadata layers. We envisage a future CCI platform capable of providing insight into phenomena such as the intellectual structure of an emerging topic, the quality of the online discourse, how the social network relates to recommended courses of action, how stakeholders are framing problems, what the claimed gaps in understanding are, the assumptions being questioned, and the diverse forms of reasoning being deployed (e.g. technical, commercial, political, ethical).

The CCI challenge is not only to operationalize meaningfully the concepts and processes central to such narratives in order to make them more computationally tractable, but also, to ensure that these remain amenable to human inspection and reasoning, to enable continued social negotiation over the legitimacy and significance of artifacts in the system. The evidence from systems that seek to automate reasoning through knowledge representation techniques is that analysts reject 'black boxes' they cannot interrogate, preferring information management tools with intuitive visualizations that leave them in control of higher order reasoning and judgments about the significance of a data point or argument (Lowrance et al. 2008). A CCI platform should make transparent why, for instance, it represents two documents as being in a contrasting relationship, or why the collective view seems to be that the evidence for one course of action is strong.

In the final part of this section, we focus on discourse. It is a relatively mundane observation that we 'get things done' in organizations by talking a lot: building trust and sufficient common ground to frame problems in meaningful ways, and commit to mutually acceptable actions. However, this provides the springboard for our argument that CCI is a distinctive form of CI points to the centrality of *discourse* in the construction of meaning. We use this term to cover verbal and written interaction from informal, relatively unstructured interaction (typical of social networking platforms and blogs), to more structured deliberation platforms, to the careful mapping and analysis of evidence and options, to the extended texts one finds in blogs, news, and organisational reports. These forms are not a prerequisite for all forms and foci of CI, but without discourse, it is hard to imagine how we can support the kinds of intellectual and social processes we have motivated.

In addition to the preceding discussion, we briefly note several other strands of work converging on discourse as a phenomenon of first order importance. On an historical note, we note that our focus on discourse-centric CCI finds its roots in Engelbart (1963), who argued for "Dynamic Knowledge Repositories" to capture key elements of the collective dialogue. Nearly half a century later, the *social* web, attracting such interest within the CI community, evidently involves a lot of talk, as well as media sharing, tagging, rating, and so forth. From an innovation perspective, Hagel et al. (2010) point out that much of the relevant knowledge in novel, emergent domains and social systems has not yet been formally codified— indeed may not be amenable to formalization. Rather, social relationships and interaction are central to innovation, diffusion and resilience in very rapidly changing environments.

We have conceived CCI as being particularly focused on contrast, surprising results, and novelty as phenomena relevant to sensemaking, critical thinking and knowledge-building discourse. Earlier, we cited the sensemaking research of Weick and Snowden, which emphasises the importance of staying open to multiple interpretations. Once a set of competing viewpoints has been identified within a CCI platform, how can these be analysed? It is not surprising to find relevant work within the intelligence analysis research community. We already referred to Lowrance et al.'s (2008) work on the Structured Evidential Analysis System, which uses a template-driven approach to mapping evidence, and van Gelder's (2002) work on Argument Mapping provides disciplined mapping techniques that aid in critical thinking. The influential work of Heuer (1999) on Analysis of Competing Hypotheses (ACH) was designed specifically to prevent analysts' confirmation bias through matrix analysis of competing hypotheses (ie. potentially plausible "narratives", in our earlier terminology). ACH-based tools clearly scaffold knowledge-building discourse in a disciplined way, for instance, CACHE (Convertino et al. 2008; Shrager, et al. 2010), provides a collaborative ACH space for the exploration of hypotheses in open science, uses notification spreading through provenance chains in order to simplify revision updating, marking questionable results, and informing scientists when their hypothesis or claims potentially need to be revised. Interestingly, just as intelligence analysis tools such as ACH provide support for detailed analysis of competing options that might be expressed in a collaborative discourse platform such as Cohere, we note that Smallman (2008, p.334) notes the need within the intelligence analysis community for better support in argument analysis and visualization, of the sort provided by Cohere, or Rationale (van Gelder 2002).

Finally, CCI's focus on discourse is motivated by Computer-Supported Collaborative Learning (CSCL) research. *Learning*, both personal and collective, is tightly coupled to the concept of CCI, given the emphasis on conceptual change, substantive reasoning, and plausibility. Within CSCL, many theories of learning draw attention to the central importance of different forms of "talk" in the mediation and construction of learning, and the potential role of collaboration tools. It is beyond the scope of this article to survey these, but several sources of relevance are as follows. Language plays a pivotal role in the work of Vygotsky, a theoretical lens which is now being applied to organisational learning (e.g. Ghosh 2004). Andriessen et al. (2003) explore in detail the role of computer-supported argumentation in "confronting cognitions", while Scardamalia and Bereiter (1994) set out the concept of intentional knowledge-building environments, of which the Cohere tool used in this study is an example. Mercer (2004) has developed an influential sociocultural theory of learning which draws attention to the central role of dialogue. Validated in the analysis of online discussion, Mercer's categories of Disputational, Cumulative and Exploratory talk echo many of the forms of discourse we see in both organisational and public online platforms, with Exploratory talk reflecting the most reasoned form of discourse that promotes the open, critical learning orientation that is likely to build effective CCI.

Having presented the rationale for a CCI infrastructure grounded in reflective discourse, we turn to one strategy for realizing this: the grounding of discourse in source documents through annotation.

3. Enabling reflective social discourse through annotation

The traditional document mediates the construction of knowledge in organisational life in many ways which have been well documented within the CSCW community's studies of digital and paper forms (e.g. Sellen and Harper 2003). Extending the definition of document to more recent forms of online textual communication within and beyond an organisation, it seems safe to assert that documents will often be the starting points for discussions worth capturing in a CCI platform. We will later explain how in texts, discourse markers provide a powerful cue to the presence of claims, contrasting ideas and argumentation, which motivates the automated annotation technique we are experimenting with. First, however, we briefly review the role of human annotation, before introducing a socio-semantic web annotation application focused on discourse.

Levy and Marshall (1995) note the importance of annotation in intellectual work as follows:

> "Annotation is a key means by which analysts record their interpretations of a particular document; in fact, annotation often acts as the mediating process between reading and writing.
>
> Analysts generally do not take notes by writing their observations down on a separate sheet of paper or in a text editor.... Instead, they mark on the documents themselves…They highlight segments of text (sometimes whole paragraphs) and they scribble marginalia, sometimes noting where what they have seen in the text differs from what they would expect to see ("Not true!"). They also print automatically marked text, documents retrieved from databases that have the keywords that triggered retrieval or filtering explicitly marked (usually underlined). These marking practices increase the value of the documents to the analysts and form the basis for their personal and shared files."

Annotation is a means to make metacognitive activity explicit, to reflect on personal reflection. This activity is particularly important when dealing with information-intensive intellectual tasks, which require powerful scaffolding of thinking and reflection (Lin et al. 1999). By annotating texts, analysts record their reflections and therefore can use them to further reflect on their own thinking and understanding.

At the same time, within a social environment, annotations can be used to disclose multiple perspectives and to inspire new thoughts, or to enrich the work of others. Recent studies argue that social annotation has a positive effect on several sensemaking tasks such as reflection, self-analysis and examination of changes (Rich and Hannafin 2009), assessment and learning (Kalnikaité and Whittaker 2008). Reflection and annotation as social activities have proved important both from theoretical and technology design points of view. Sociocognitive theories, in particular social constructivist theories, provide a conceptual framework in which knowledge construction is a highly social activity and it requires "the dialectical interplay of many minds, not just one mind" (Goodman 1986, p.87). Therefore, in order for new knowledge to be constructed, reflections and annotations need to be shared within a community in a social interaction environment. Individual expertise needs to be combined to build distributed expertise, which is constructed through social collaboration and artifacts (Brown et al. 1983; Pea 1993).

This is well exemplified by Lin et al. (1999) with respect to peer editing conferences that help the authors shape a written product:

> "The feedback from the group sharpens and guides reflection by the author, leading to revision of what was written in ways beyond what would be possible if the individual was limited to his or her own thoughts. Reflection, therefore, while individual at one level, can also be reflective social discourse."

Lin suggests that one of the key characteristics for technology to support reflective thinking is to support social discourse. Therefore the question is: how can we scaffold reflective social discourse by building on individual users' annotations and reflections?

In the discourse-centric annotation framework that we propose, annotation is carried out with two technologies:

1. automatic text analysis, which detects discourse conveying contrasting ideas within documents

2. a platform, which provides users with a structure for annotating documents as well as with tagging and querying functionalities

The hypothesis underlying *automatic* discourse annotation is that it increases the value of the documents by providing users with automatic mark-up of contrasting ideas, which they can choose to use for enhancing their personal and shared annotations. The hypothesis underlying the utility of the *human* annotation tool is that the annotations thus registered can provide the first step and bootstrapping information toward the development of reflective social discourse among the members of the organizations.

Based on this theoretical background and framework, a CCI system, as we conceive it, is a system that enhances reflective thinking and discourse by providing an environment for human annotation—both individual and social—as well as automatic annotation of documents. Users can record their thoughts by creating annotations at the margin of documents, in the process reflecting on their own thinking as they give form to it (a key dynamic in sensemaking), while also encountering others' annotations which confront them with confirmatory and challenging perspectives. Discourse-centric annotations, in this view, come to serve as shareable, improvable artifacts (Scardamalia 2002), and objects for reflection.

4. Human and machine discourse-centric annotation technologies

We have argued above that CI technologies (see Malone et al. 2009 for a useful categorization of different CI technologies) are designed for enabling users to express interpretations so that, at least in theory, others can reflect, build on and learn from it. Moreover in Section 3 we have also presented the rationale for considering annotation as a core component of a CCI platform. We now describe a conceptual model which explains how document annotations can facilitate social discourse to support sensemaking as “the process of searching for a representation and encoding data in that representation to answer task-specific questions” (Russell et al. 1993).

Sensemaking, in Russell et al’s view, is the process of identifying a schema which helps to structure and understand information. Russell et al. argue that there are two main approaches to help a group or organization to handle problems that involve large amounts of information: the Information Retrieval (IR) approach and the sensemaking approach. The sensemaking approach considers IR as a subtask of a larger overall task structure in which the retrieved information is encoded to answer task specific questions (Russell et al. 1993).

In our conceptual model, human and machine annotations enhance the IR subtask by preprocessing the data for the sensemaking activity with the aim of reducing the cost of the sensemaking process. The model comprises four stages (Figure 1).

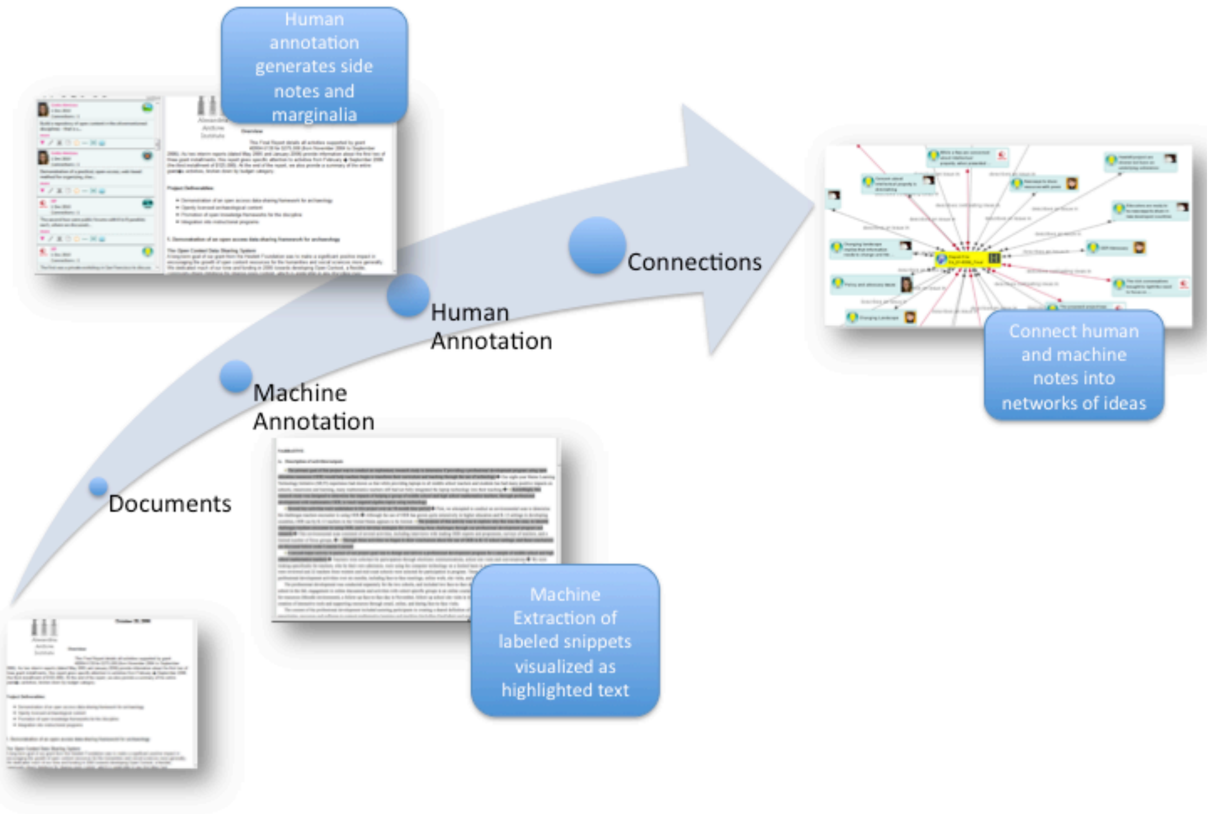

Figure 1. Conceptual model of the CCI platform

Stage 1 begins with whatever documents form the current working set for the analyst: papers, reports, diagrams, charts, etc. The members of organizations usually work as information analysts, and read documents trying to identify and extract information and knowledge which can be relevant for the issue they have to investigate. Without any computer assistance the analysts have to read the full documents and make sense of them. They often support the process of sensemaking by taking notes and marginalia. Their annotations mark up key issues, which may be relevant to the problem, or may be surprising, or contradicting the reader's expectations. Once the notes have been taken they may be used to reflect on the contents of the document, and on what they may imply for the contingent inquiry. Our model aims at assisting the analysts by proposing tools and computer infrastructure to carry out these tasks.

In Stage 2 automatic text analysis technologies are used to further retrieve from the document database relevant passages conveying contested ideas, which the analysts can choose as entry points to reflective thinking. Machine annotation produces two main kinds of output as visual artifacts: sentences and labels. Sentences represent salient contents extracted from the document, and the labels indicate the semantics of the link between the salient content and the document or part of the document.

Stage 3 is human annotation: analysts can validate some of the automatically suggested text snippets and add their interpretation, or they may highlight and comment on new snippets, and thus create further visual artifacts. If the documents are shared by a group of analysts, all the annotations can be used. Human and machine annotation can thus be combined to provide analysts with a view of the salient contents in the document.

Finally stage 4 is the process of encoding the retrieved information to answer specific questions. This is supported by the specific sensemaking activity of "making connections". This is a key activity to enable sensemaking as Klein et al. (2006) conclude:

> "Sensemaking is a motivated, continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and act effectively. […] A frame functions as a hypothesis about the connections among data."

Therefore to effectively support sensemaking we aim at enabling analysts to generate a structure which works like a hypothesis about the connections among data, and which helps analysts to construct their narrative. This narrative is visualized so that it can become an artifact for social sharing and further reflection in the analysts' sensemaking process.

In our conceptual model stages 2 and 3 produce visual artifacts to be used in stage 4 for making connections: Both machine and human annotation result in two kinds of visual representations: what are termed *ideas*—which are either extracted from the document (stage 2) or added by analysts (stage 3)—and *connections* that anchor the ideas in the documents. In stage 4 human and machine annotations are integrated into new visual artifacts which show human and machine annotations together, and critically, which permit the viewing and crafting of meaningful connections between annotations. This semantic network can be rendered in many ways, providing materials to inform and provoke wider discourse grounded in documents, but also in the central ideas that have been read into them by the community.

The stages do not indicate a sequential order of the processes in our model, i.e. the steps can be re-iterated in several direct/reverse loops. Hypothetically we envision that within the conceptual model of a CCI platform, machine annotation comes first, since it requires much less time and, more importantly, it can provide useful bootstrapping information that can support readers in their analysis. However, developing the modalities of the combination of human and machine annotations in a working system is subject to further research.

The conceptual model that we have described follows a mixed-initiative approach and seeks to couple automated services with direct human manipulation, in an attempt to take advantage of the power of human intelligence and automated reasoning (Horvitz 1999;Birnbaum et al. 1996). Mixed-initiative approaches are used to mitigate the inevitable errors of the automatic extraction of semantic information from unstructured data (Kong et al. 2011) as well as to accomplish goals that are unachievable by human or machine processing on its own (Tecuci et al. 2007). In this latter case, mixed-initiative approaches strongly overlap with the very essence of Collective Intelligence research, which aims at investigating "How can people and computers be connected so that—collectively—they act more intelligently than any individuals, groups, or computers have ever done before?", [1]

Compared to Pirolli and Card's(1995) model of sensemaking, our four-stage model supports the three steps of the foraging loop (External data source, Shoebox and Evidence file) and the first key step of the sensemaking loop, (Schematize). Figure 2 shows how our model (Figure 1) can be mapped into Pirolli and Card's model of the sensemaking loop.

This comparison exemplifies why the CCI infrastructure we seek to design is a sensemaking infrastructure, and how it supports the four key steps within the sensemaking loop that analysts need to go through when dealing with complex organizational issues. The analogy also clarifies that the model we propose is not sequential in terms of process, in fact steps can be re-iterated in several direct/ reverse loops, whereas the arrow in Figures 1 and 2, represents the incremental steps of increasing human effort and data structure, which are involved in the sensemaking process that analysts go through when they start form row data sources and move toward coherent hypothesis testing.

[1] MIT Center for Collective Intelligence. http://cci.mit.edu/

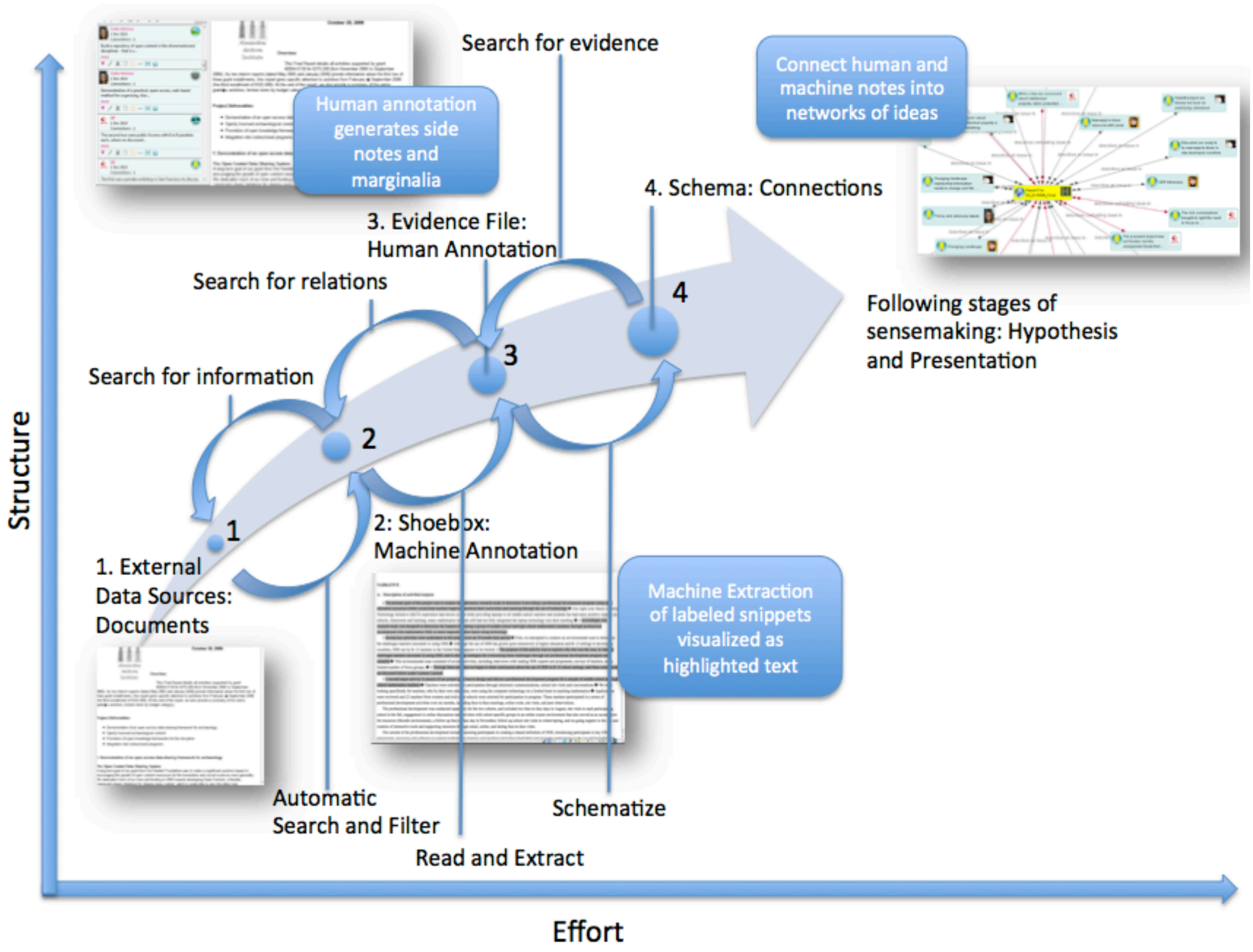

Figure 2 Adapted from Pirolli & Card's model of sensemaking loop (Pirolli,and Card, 1995).

Building on this conceptual model, in the following sections we focus our attention to technology design as a first step toward the implementation of a prototype CCI System. In this system we combine a natural language processing tool, the Xerox Incremental Parser (XIP) and a knowledge mapping and web annotation tool, Cohere. XIP (the shoebox, step 2 in Figure 2) supports the sensemaking process with automatic search and filter of relevant data: in particular XIP provides automatic extraction of sentences containing contrasting ideas. From this list of sentences Cohere produces a representation of the key issues in the document, which is proposed to trigger discussion. Cohere mediates this discussion by enabling users to add new annotations (read and extract evidences, step 3 in Figure 2) and to semantically connect them into meaningful discourse networks (schematize, step 4 in Figure 2).

5. Cohere: discourse-centric human annotation

From a research perspective, the *Cohere*[2] web application derives from work in issue mapping and design rationale (Buckingham Shum et al. 1997, Conklin & Begeman, 1988), computational modeling of argumentation (Buckingham Shum 2008) and computational modeling of scholarly discourse (De Waard et al. 2009, Uren et al. 2006). Viewed through the lens of contemporary web tools, Cohere sits at the intersection of web annotation (e.g. Diigo[3]; Google Sidewiki[4]; SparTag.us Hong et al. 2008), social bookmarking (e.g. Delicious[5]), and mindmapping (e.g. MindMeister[6]; Bubbl[7]). Cohere scaffolds users to: i. collaboratively annotate web resources; ii. create meaningful semantic connections between annotations and iii. make sense of complex issues by exploring, filtering, debating and better understanding other people's thoughts. Similarly to other collaborative web annotation tools such as Diigo, SparTagus etc., Cohere enables users to add margin notes in web pages (via a Firefox web browser extension), associated either with the entire page (URL) or with specific snippets of text in the page. When users create an annotation it appears in the sidebar of a web browser and is also added to their personal archive, from which they can view and browse their notes and ideas.

Unlike other web annotation tools Cohere combines web annotation with knowledge mapping. Knowledge mapping is a technique used to represent knowledge in the form of network maps. Different forms of mapping are described in the literature (see Okada et al. 2008 for a compendium), and are used for different purposes: e.g. to represent streams of mental associations (mind maps), to represent dialogue (dialogue maps), to support decision-making and deliberation (argument mapping). In contrast to earlier prototype tools within the CSCW literature, which sought to structure real-time discourse with a fixed ontology of node and link types (e.g. Conklin and Begeman 1988), Cohere is (i) designed for asynchronous use (hence the cognitive overheads are substantially less than synchronous meetings), and (ii) provides customizable types which can be as simple or expressive as the individual, or collective, choose to meet their knowledge capture requirements. Its text annotation capability also reflects a key lesson from early design rationale research, which disconnected collective reflection from the relevant artifacts (Buckingham Shum et al. 2006).

In Cohere, we use mapping to represent how annotations and open ideas are connected into a wider network of notes and ideas, with the overall goal to generate an interactive representation of the social discourse beneath Web documents, and the users'

---

[2] http://cohere.open.ac.uk

[3] http://www.diigo.com

[4] http://www.google.com/sidewiki

[5] http://www.delicious.com

[6] http://www.mindmeister.com

[7] https://bubbl.us

interpretations of those documents. To create this representation users can contribute independently, and are not constrained to using any specific communication language.

In a scenario that demonstrates the functionalities of Cohere, two analysts investigate a specific climate change issue by analyzing Web documents. They create a "Group" in Cohere called "Climate Change Inquiry", where they can share all the documents they read, together with the annotations they make to those documents, and the tags they associate to both documents and notes. Figures 3 and 4 show two web pages annotated independently by the two analysts. Figure 3 shows an annotation from 'Ivana': "Maldives cabinet holds underwater meeting" in the browser's sidebar. Highlighted in blue in the Web page we find the snippet of text to which 'Ivana' associated her annotation.

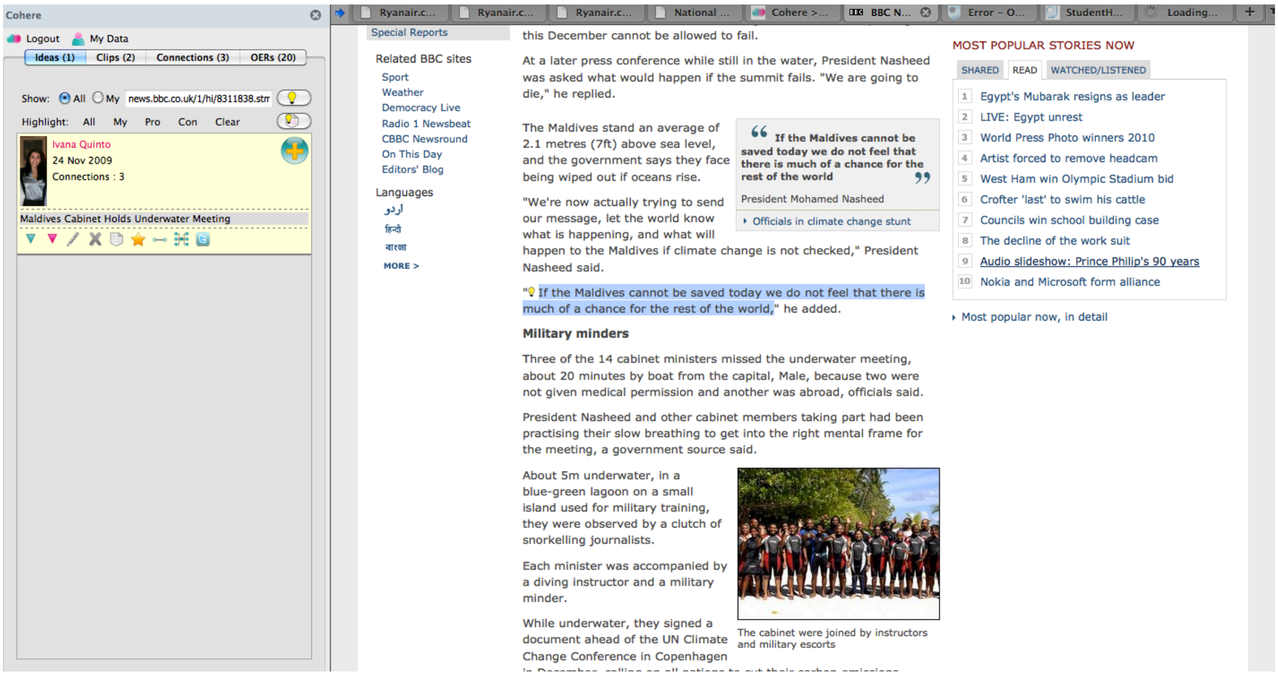

Figure 3. Cohere's Firefox sidebar shows users' annotation to the page and the snippet of text to which the annotation refers (highlighted in blue)

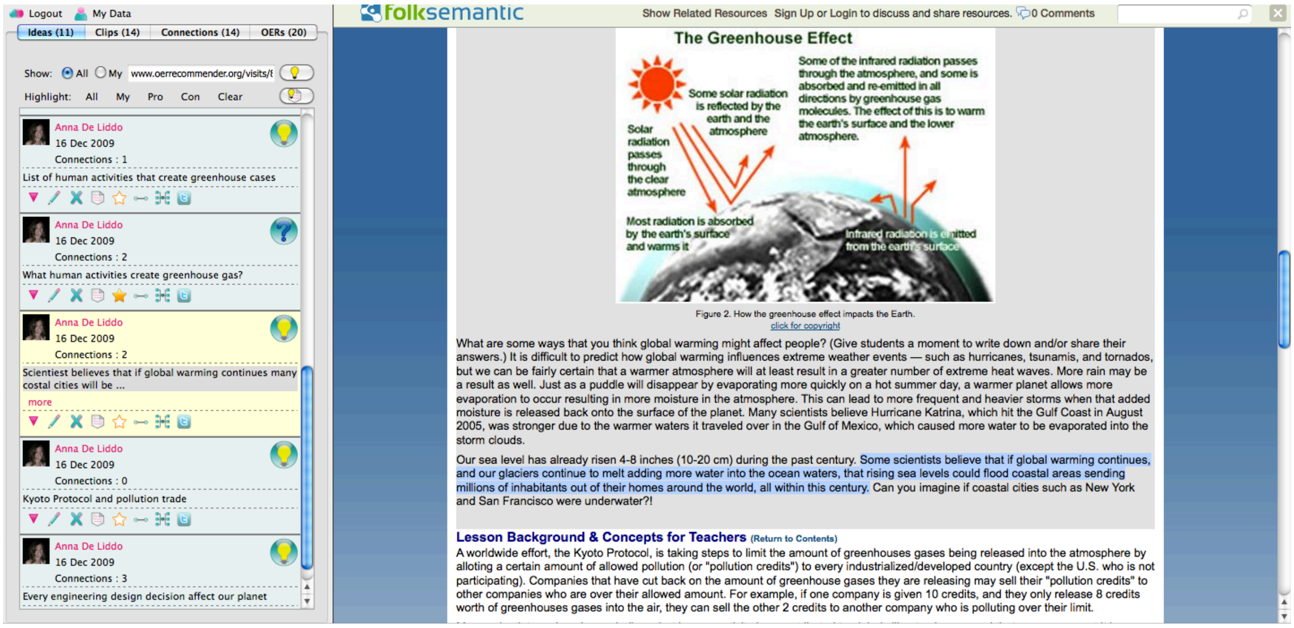

Figure 4. Cohere's Firefox sidebar shows several annotations to the page. Icons at the top right corner of the note show different types of annotations (e.g. Questions and Ideas)

Similarly in Figure 4 we see another Web Page to which 'Anna', has associated several annotations as side notes. By clicking on a note it is highlighted in yellow in the sidebar, and the Web page scrolls down to highlight in blue the snippet of text to which the note has been associated.

Cohere provides also additional classification of the annotations by type. Each annotation type is associated with an icon, which is visible at the top right corner of each note in the sidebar For example in Figure 4 all the notes have been classified with a "light bulb" icon representing a general idea, and one note has been classified as a "question mark" icon: "?". As we will exemplify later (Figure 5) these annotations icons provide quick visual hints on the roles of each annotation within a social discourse

Document-centric annotations are important, but they do not indicate if the two documents in these examples are related in any way. Neither is it possible to know how the annotations fit into a wider social discourse on climate change, which other analysts may be undertaking at the same time, using different web resources.

To move from a document-centered view of annotations Cohere enables connections between annotations from different web pages and from different users. Users can connect not only their own annotations but they can also connect to other users' annotations. This results in a social network of document annotations.

When the network is generated it can be visualized as a network map (Figure 5).

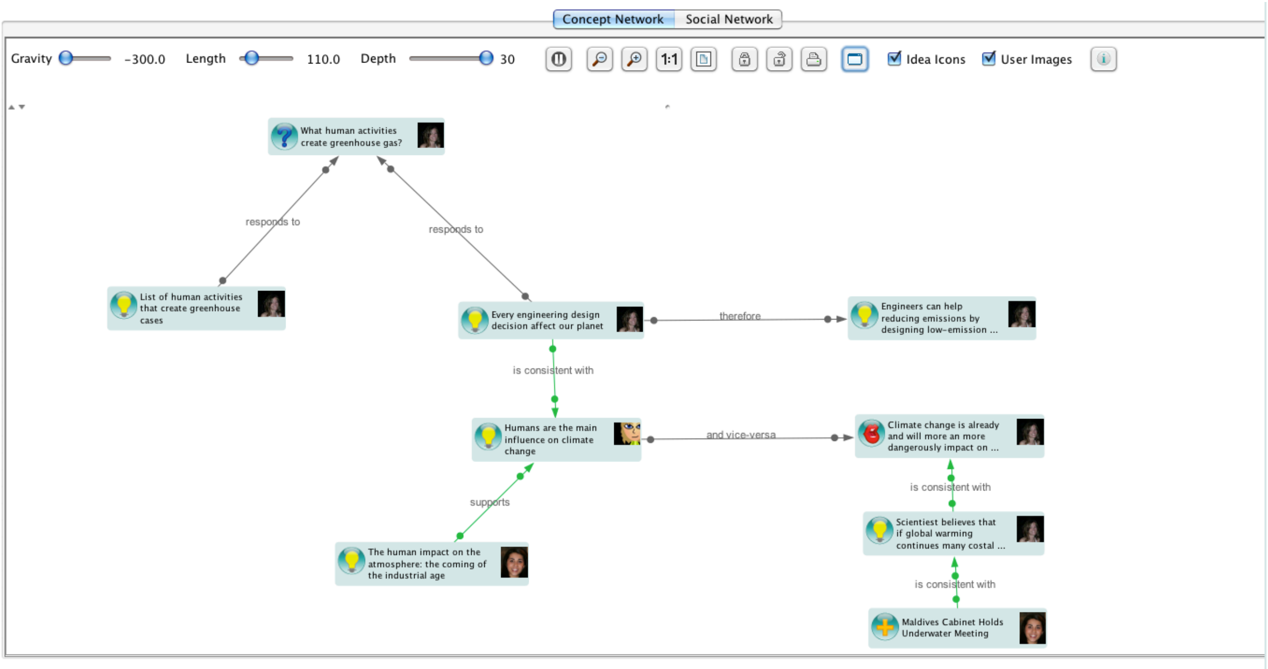

Figure 5. Network of annotations showing relationships between notes from a group of analysts working on different web documents. Each node has two (optionally displayed) images: the author of the annotation, and the annotation type. Connections have free-text labels as cues to the nature of the relationships between annotations.

Cohere's network visualization is generated by a Java Applet developed using the open source *Prefuse* visualization code from PARC.[8] The network visualization can be launched from many different places in the Cohere Website, i.e. it can be launched from the analysts' group page. Group annotations can be also filtered by tag and user, in order to show e.g. all the networks of annotations that share a specific tag, or that have been created by a specific analyst.

Figure 5 represents the annotations which the example-group of analysts have created and shows how they have been semantically connected. Semantics are expressed by link labels within the annotation network. Link labels are manually assigned by the analyst who creates the connection, either by picking on a preexisting list or creating new ones (to know more on creating connections and labels in Cohere see De Liddo and Buckingham Shum 2010).

By exploring the semantic network of annotations analysts can see how their notes sit in the wider social discourse around climate change. For instance in Figure 5 we can see that the annotation by 'Ivana' on the first document (Figure 3) *is consistent with* the annotation made by 'Anna' on the second document (in yellow in Figure 4). We can also see from the network map that these annotations (at the bottom-right corner in Figure 5) are *consistent with* another note which states that "Climate change is already, and will more and more, dangerously impact on human life".

---

[8] http://prefuse.org

By looking at the whole map, analysts can get a sense of the wider social discourse on climate change and can see where their notes actually sit in this wider conversation and in the overall group work. They can see who else is involved in the conversation and who has taken notes directly or indirectly related to their own notes.

Through this example we have illustrated how Cohere, by enabling the mapping of annotations, provides an interactive environment for structured online social discourse. This environment supports two of the key activities outlined in the conceptual framework to implement CCI: annotation and making connections.

6. XIP: cohere: discourse-centric machine annotation

As mentioned before, automatic analysis for CCI highlights discourse units that convey controversial issues. In this section we first describe how these discourse units are defined, and then the technology applied for their detection.

We aim at highlighting relatively short but still informative, synthetic units which—besides main TOC (Table Of Content) elements such as title, possible section headings, keywords and abstract—shed light on the controversial issues dealt with in the text, or indicate the parts of the texts where these issues are dealt with. At the present state of the development of XIP these informative units are sentences.

In the experiment of integrating XIP with Cohere we follow Sándor and Vorndran (2010) where synthetic sentences referring to controversial issues are identified in sentences conveying two kinds of rhetorical functions: “summarizing” and “contrasting ideas”.

“Summarizing” is a function by which the author can refer to the issues dealt with in (parts of) the text. In the following examples the issues are in italic, whereas the parts of the sentence carrying out the rhetorical function of “summarizing” are in bold:

> **“The purpose of this article is** *to develop the idea that the procedures in any given classroom or laboratory exercise should be definitely determined by the specific aim, which the instructor has in mind to accomplish.”*
>
> **“The perspective I shall use in this essay** *relies heavily on the view of professionalization presented in Andrew Abbott's brilliant study, The System of Professions (Abbott, 1988).”*
>
> **“This paper explores** *social practices of propagating ‘memes’ (pronounced, ‘meems’) as a dimension of cultural production and transmission within internet environments.”*

Authors carry out the rhetorical function of “contrasting ideas” when they contest, question or point out as significant or new some issues, facts or theories, when they indicate a gap in knowledge, or point out any flaw or contrast related to the subject, etc. In the following examples, like in the previous ones, the controversial issues are in italic, and the parts of the sentences carrying out the rhetorical function of “contrasting ideas” are in bold:

> **"With an absence of detailed work** *on masculinities and sport in South African primary schools (for an exception, see Bhana, 2002)* **this paper goes some way towards addressing the issues around** *young boys' developing relationship with sport."*

> **"My interest of inquiry emerged** *in 1997 from a new idea in school pedagogy and sport pedagogy."*

Sentences conveying contrasting ideas maybe be further categorized into subclasses like novelty, surprise, importance, emerging issue and open question.

As the example sentences illustrate, the rhetorical functions are conveyed by some dedicated expressions. These are the expressions that the automatic analysis captures in order to highlight the sentences conveying controversial issues.

The detection of sentences conveying controversial issues is carried out by the Xerox Incremental Parser (XIP) (Aït-Mokhtar et al. 2002). XIP provides formalisms for encoding grammar rules for analyzing texts. The *controversial issue* analysis functionality is implemented by grammar rules that detect particular discourse functions conveyed within sentences. It is based on the concept-matching discourse analysis framework (Sándor 2007).

The concept-matching discourse analysis framework considers discourse functions as complex concepts that are conveyed through syntactically coherent configurations of constituent concepts.

The following examples illustrate the application of the concept-matching analysis framework for detecting the discourse functions of "summarizing" and "contrasting ideas" in the example sentences we presented above. The constituent concepts are in angle brackets in capital letters.

Summarizing:

> "The purpose of this[DEICTIC] article[PUBLICATION] is to develop[MENTAL-OPERATION] the idea[IDEA] that …"

> "The perspective I[DEICTIC] shall use[MENTAL-OPERATION] in this[DEICTIC] essay[PUBLICATION] …" "This[DEICTIC] paper[PUBLICATION] explores[MENTAL-OPERATION] …"

Contrasting ideas:

> "With an absence[CONTRAST] of detailed work[IDEA] … addressing[MENTAL-OPERATION] the issues[CONTRAST,IDEA] …."

> "My interest[ATTITUDE] of inquiry[IDEA]) emerged … from a new[TEMPORALITY] idea[IDEA]) in …."

By implementing this framework of analysis XIP can be used to automatically extract sentences which convey contrasting ideas and summaries of key content in a document.

We have used XIP as the second prototype component of the CCI platform. XIP provides Cohere with the component of machine annotation, and at the same time Cohere provides XIP with a visual interface for interacting with the results of machine annotation. Moreover machine annotations can be connected with human annotations and contribute to the wider social discourse as described in Section 5.

7. Case study: integration of human + machine annotation

We explored the XIP-Cohere integration in a case study. We used both tools in answering the need of an international funding body to improve their understanding of the state of the art in research in a particular domain, Open Educational Resources. In a scenario familiar to many organizations, a team was presented with a large collection of documents—125 reports of a great variety of projects funded over 10 years—and asked to provide collectively a summary of what has been learnt, and on the implications for future planning. Examples of the funder's interests were emerging themes, whether some stakeholders could be learning from others, who the major and emerging stakeholders were, and what the major unresolved and contentious challenges were. Figure 6 shows the methodology adopted, with human and machine analysis of the corpus conducted independently to enable us to compare performances.

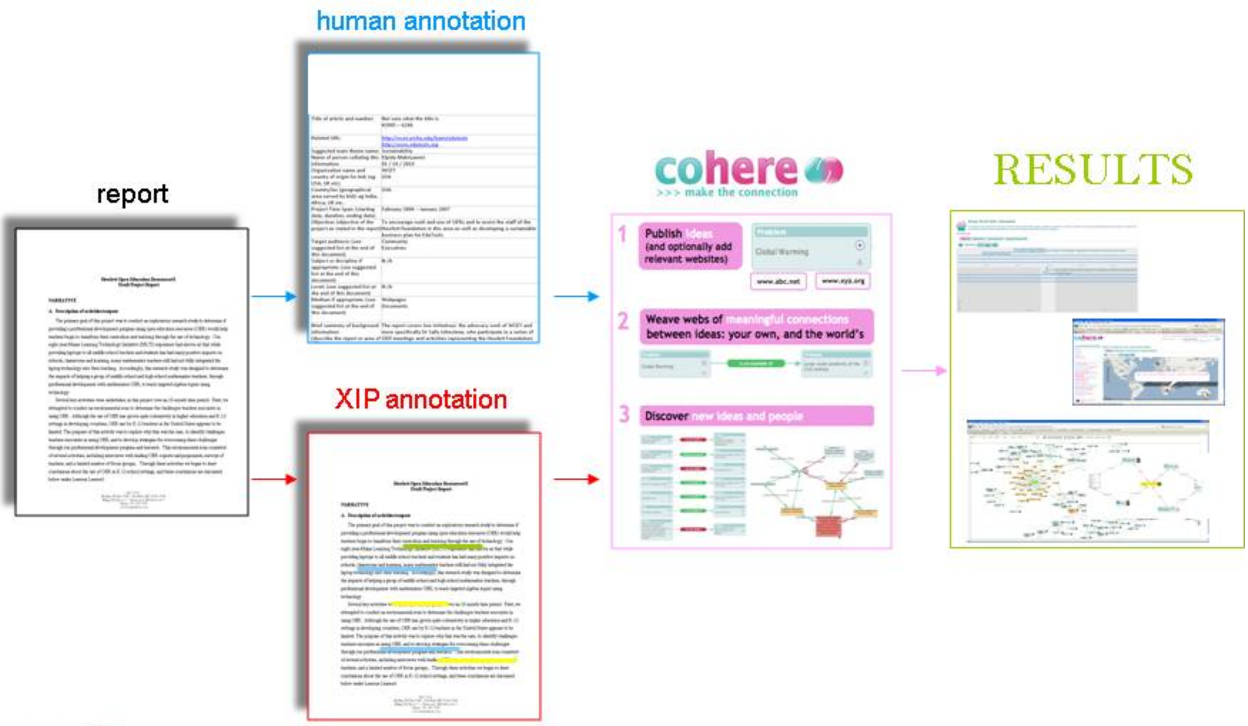

Figure 6: Methodology: Reports have been analyzed in parallel; results of annotations have been imported into the Cohere system for data integration and for generating several mash-up visualizations.

Five analysts independently annotated the reports by completing an Annotation Template (Figure 7), which had been co-designed with them to focus their attention on annotating relevant information for the funding organization as well as to provide a common guidance and goal to each analyst. This form provided a simple interface for analysts, which Cohere could convert into many semantic nodes and connections in its database.

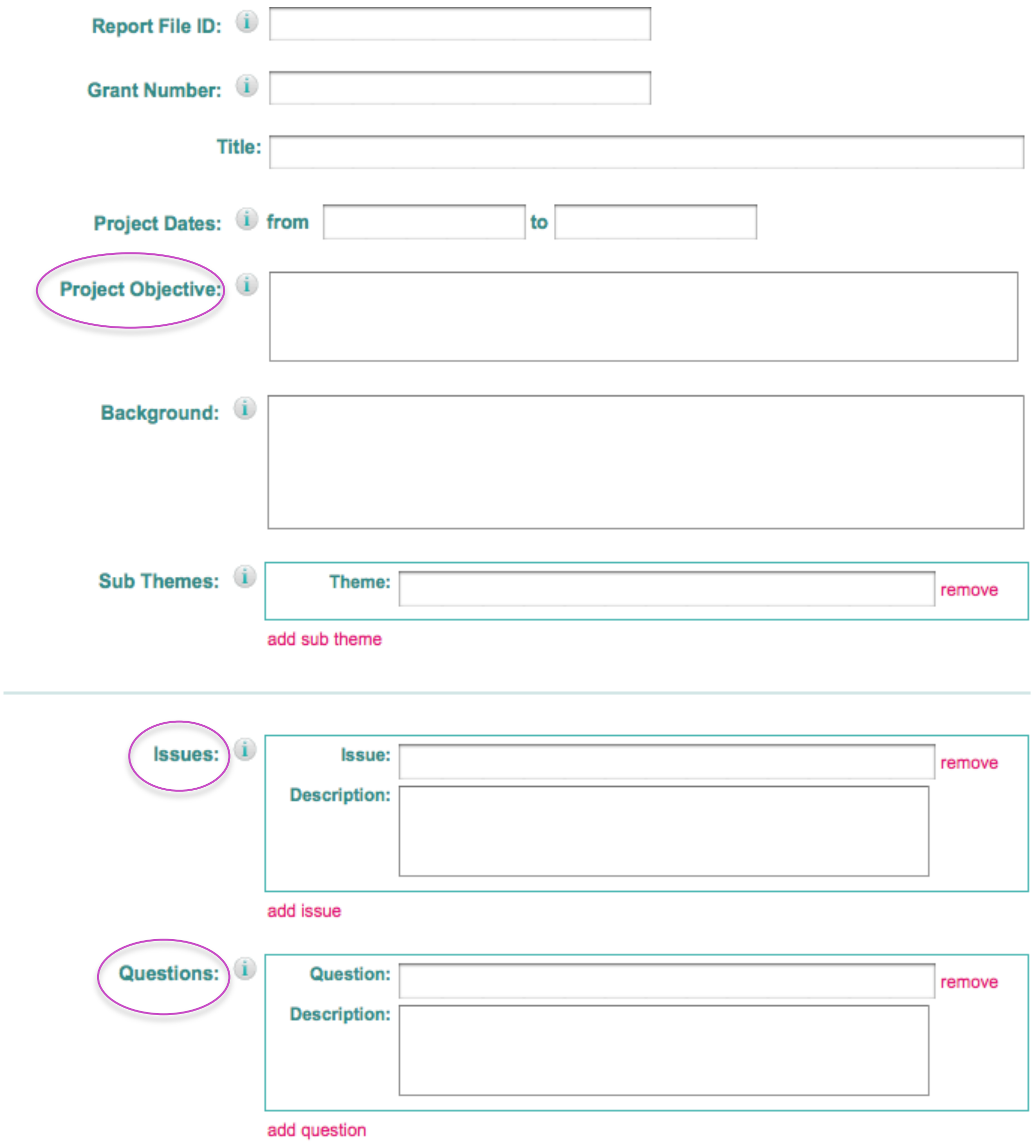

Figure 7: Extract from the Annotation Template used to fill in the results of human analysis on the reports. The pink circles indicate the fields used to compare human and machine analysis.

The Annotation Template was developed within the Cohere Website, so that the analysts could simply log in to the system and use it as a simpler interface to create annotations. Those annotations were then automatically imported from the Annotation Templates into the Cohere platform. A data model for the import was specifically designed to this purpose. Similarly, the XIP results were imported into Cohere so that as the results of human and machine annotations could be explored together within the Cohere system.

The data model in Figure 8 shows the information schema for the import indicating what data we imported and how we visualize them within Cohere.

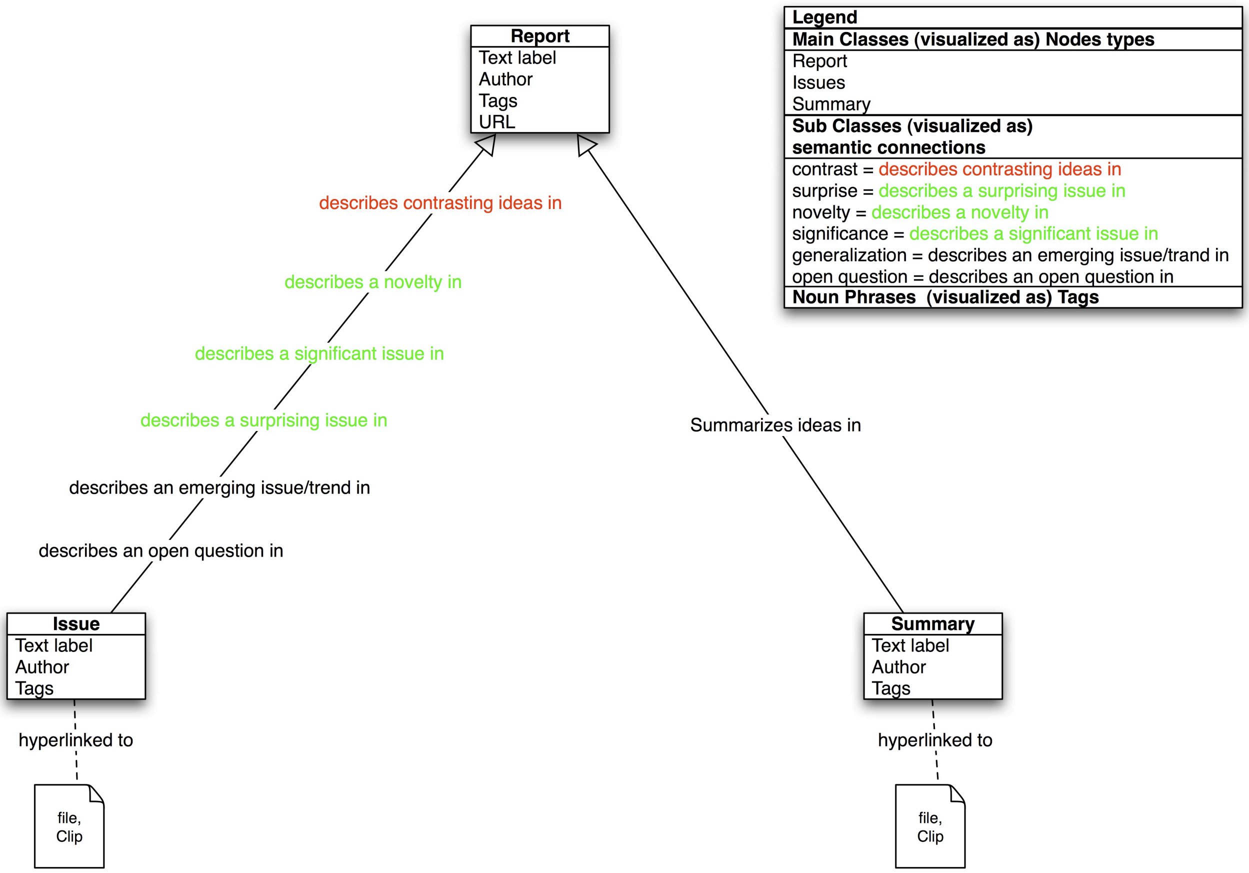

Figure 8: Data Model for XIP and (Simplified) Annotation Template import to Cohere.

The analysts read the reports and formulated the responses in the Annotation Template as free text. This form was imported in Cohere following the data model in Figure 8. The import consisted in mapping the analysts' annotation texts into annotation nodes, while the corresponding fields within the Annotation Template were converted into semantic links (e.g. "objective for", "issue for", "research question for", "background for", "sub-themes of", etc.) that connect the nodes with the central node of each analyzed report.

Figure 9 shows how an extract of the Annotation Template (pink box) is converted into Cohere data. The analyst's annotation text "*Diversity in subject matter*" is converted in the Annotation Node label; the field of the form named "issue" is converted in the semantic link "*describes an issue in*". Other fields of the Annotation Template such as Collator Name (name of the analyst), Title, etc. are also represented in the Report Node label.

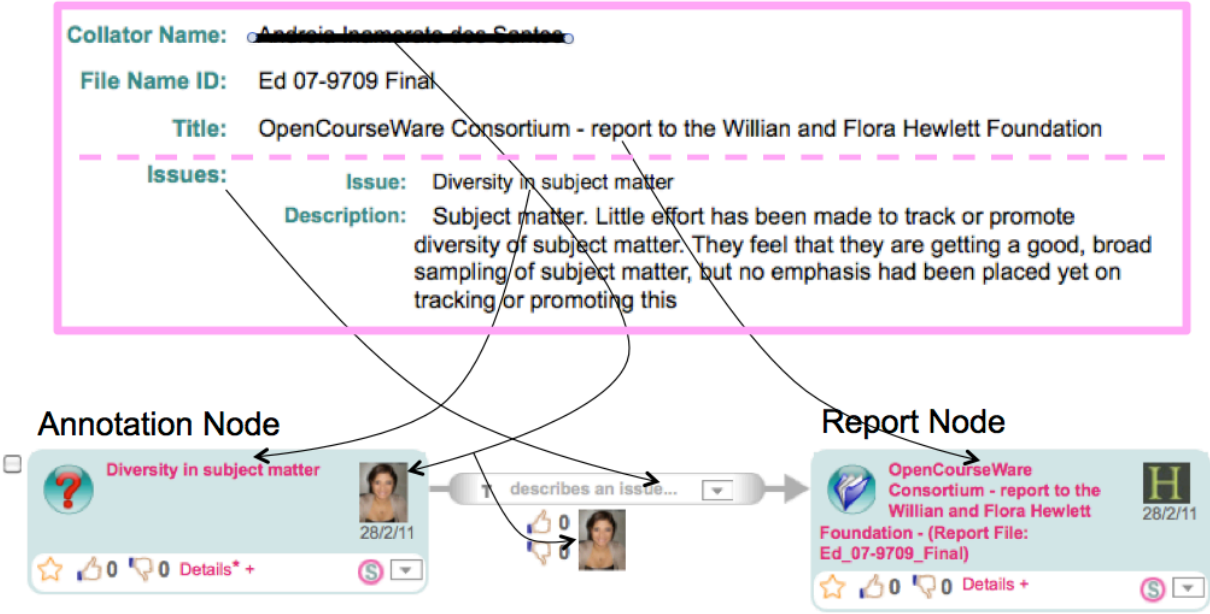

Figure 9: Extract from the Annotation Template (pink box) converted into Cohere's data, that is, a triple data structure comprising Annotation Node–Semantic Connection–Report Node.

The XIP results were imported into Cohere in a similar way: The sentences extracted by XIP from the reports were imported as Annotation Nodes and their labels as semantic links to the central node of each report (see Figure 10). The semantics of the links is either "issue for" or "summary for" (as according to the import data model in Figure 8), meaning that the sentence conveys an issue, i.e. contrasting ideas, and/or a summary with respect to the topic of the document.

Figure 10 shows an example of how XIP results (blue box in Figure 10) are converted into Cohere's semantic connections, i.e. into a triple *Annotation Node–Semantic Connection–Report Node*. XIP extracts sentences from the report texts and classifies them according to specific main classes and subclasses (i.e. PROBLEM = higher class; CONTRAST = subclass; SURPRISE = subclass; NOVELTY = subclass, etc.). Higher-level classes are visualized as ICONS of the annotation node (i.e. "light bulb" = PROBLEM); whereas subclasses define the label of the semantic connection (i.e "*describes contrasting idea in*"). All annotations within the analyzed documents converts into triple of this sort and can be explored as a network graph of annotations (Figure 11).

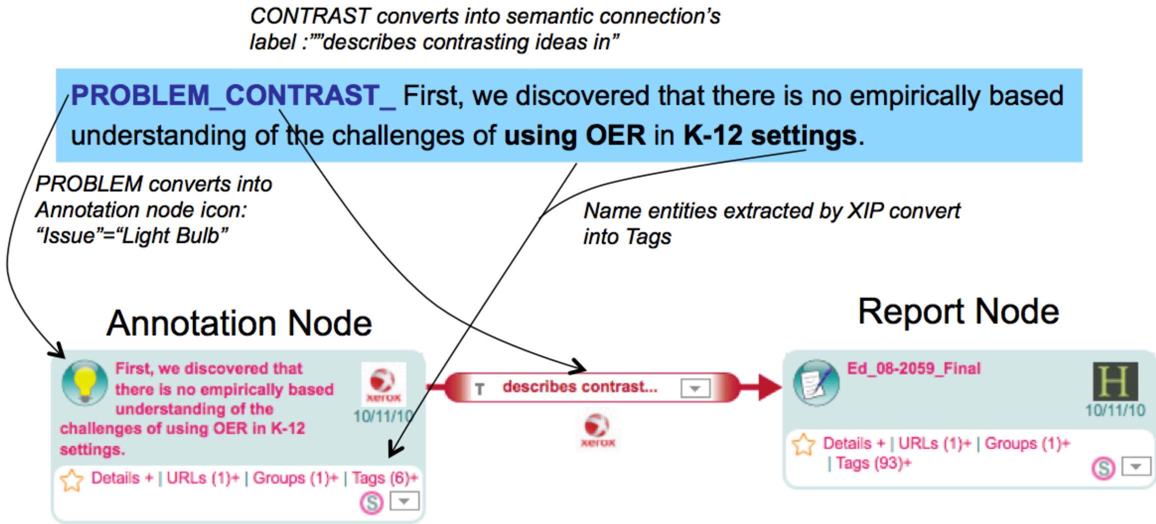

Figure 10: Example of a XIP extracted sentence (blue box) converted into Cohere's data, that is, a triple Annotation Node–Semantic Connection–Report Node.

By importing the results of the human and machine analyses into the Cohere system we created a knowledge repository of annotations, which provided the first set of CCI artifacts. The repository is populated by both human and machine annotations, which are semantically linked to the same central node. The repository can be explored by exploiting different visualizations offered by Cohere: timeline view, connections list, geographical view and a network map of annotations. The network map of annotations (Fig. 11) is a key representation for enabling the CCI concept since it provides a structured representation (the sensemaking schema) for triggering a wider social discourse on the content of the documents: the network of annotations provides key issues, questions and ideas within the document. Several analysts can then connect to the network thus enabling sensemaking across documents, topics and people.

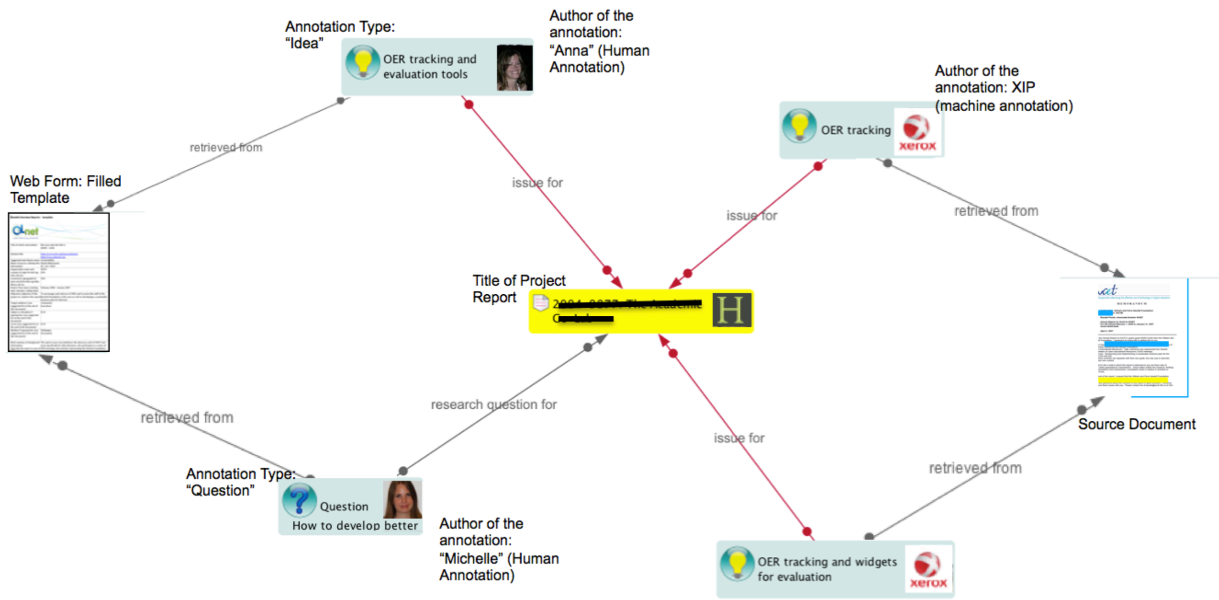

Figure 11: Social network of document annotations to which XIP contributes as an agent. Each annotation is hyperlinked to the source document.

By navigating, querying, filtering and visualizing the social network of annotations the organization can explore the collective views on the contents of the reports, as suggested both by the automatic analysis and by human interpretation provided by the analysts.

As described next, as a first step in the evaluation of the XIP-Cohere integration, we have compared machine and human annotations of the same documents. This comparison allows us to gain insights on how human and machine annotation could be combined to enhance the development of CCI in organizations.

8. Comparison of human and machine annotations

As we mentioned above, the sentences detected by XIP are imported into Cohere with two kinds of semantic link—"issue for" and "summary for"—, while the human annotations, which—as we have mentioned—were both independent of and disjoint from the machine annotation, were imported with several kinds of semantic link. The consistency of the semantic links is essential for CCI, since their function is to provide structured input for the wider social discourse.

In the present case study machine annotation and human annotation formally share one common semantic link type, "issue for". However, owing to the fact that machine annotation lacks the fine granularity of human annotation, this common link name does not correspond to completely overlapping semantics in the two separate annotation sources. Thus in order to carry out the comparison we considered a coarser-grained correspondence. We merged into one single category the two machine-created links—"issue for" and "summary for"—and we also merged into one single category a group of three links resulting from the human annotation: "issue for", "objective for" and "research question for". As a result, we compared all the sentences highlighted by XIP with the sentences that the analysts wrote as answers to the three questions in the Annotation Template.

By comparing the two annotations that result from independent and disjoint approaches to text analysis we aim at evaluating their respective contributions to sense-making as well as at getting insight into the design requirements of a sense-making environment that integrates both annotations. Our initial considerations and questions are the following:

1. Machine annotation consists in sentence selection, whereas human annotation might modify the original text (e.g. paraphrase it) or might be completely different from it (e.g. comment on it). To what extent does human annotation correspond to the original text that is annotated? The answer to this question might provide clues for the modalities of using machine annotation for assisting human annotation.

2. Machine annotation is based on rhetorical markers, whereas the human annotation process is conceptually guided by the fields in the Annotation Template, and has no declared relationship with the identification of rhetorical functions. Is there, however, a latent correlation between the fields in the Annotation Template (recall that these were designed to answer the funder's and researchers' questions, completely independently of XIP), and the rhetorical functions XIP detects in the reports? The answer to this question sheds light to the effectiveness of using rhetorical function markers in the automatic annotation.

3. Human annotation is subjective: the same report is summarized by different experts in different words and at different lengths. (It is in fact impossible to get the same annotation for the same report from different human annotators, and even the same person would be unable to annotate the same report twice in the same way.) In Cohere each human annotation is valid—since the purpose of annotation is to give place to each point of view—and no annotation can be missing. This implies that there is no external evaluation of the human annotations. Contrary to this machine annotation always obeys the same rules, and it can be the case that it is not valid. In light of these differences the machine-annotated sentences that do not correspond to sentences in the Annotation Template in our comparison cannot be considered as valid or noise without human evaluation. How can we evaluate machine-annotated sentences that do not correspond to sentences in the Annotation Template?

In order to propose answers to the questions in each point we have carried out some measurements. Before describing them we give some indications about the size and scope of the comparison.

We evaluated 41 Annotation Templates, each filled in by one analyst. Altogether five analysts participated in the study with a distribution of 25, 8, 4, 3, 1 Annotation Template(s) filled in by the same analyst. The human annotation resulted in a total of 161 sentences in the three fields (Objectives, Issues, Questions) considered, while in contrast, the machine highlighted 797 sentences in the 41 project reports (i.e. about 5 times more than the analysts). The number of sentences written in the same field was variable, and in some

Annotation Templates some fields have been left blank. The average number of sentences in the three fields altogether is around 3 in the case of five annotators and 10 in the case of one annotator. The number of sentences linked to the same document may be high, and therefore for a big corpus of documents a scalability issue may arise. To mitigate this limitation, visualization of all of the sentences at the same time may be difficult. Cohere allows tag-based content filtering procedures that can reduce the number of sentences explored at a time at a manageable level.

In the following points we describe the organizational conditions in which time is constrained for comparing human and machine annotations.

To what extent does human annotation correspond to the original text that is annotated?

We considered that there is a correspondence between an Annotation Template sentence and an original sentence in the report in the following cases:

a. at least one meaningful and relevant unit of both sentences are identical

b. at least one meaningful and relevant unit of the Annotation Template sentence is a paraphrase of or synonymous with the original sentence

c. at least one meaningful and relevant unit of the Annotation Template sentence is an implication of the original sentence

The same Annotation Template sentence can show several kinds of correspondence to the report sentence. The sentence pairs in Table 1 illustrate the three kinds of correspondence. The identical parts are in bold, the paraphrases or synonyms are underlined, and the implications are in italics:

Table 1: Cases of correspondence between Annotation Template sentences and original sentences in the reports: The identical parts are in bold, the paraphrases or synonyms are underlined, and the implications are in italics (names have been substituted by letters for confidentiality)

Annotation Template sentence	Original sentence in the report
"Project Objective: **To improve** upon **the original four courses** on XYZ and work towards *contributing another 10 course approximately."*	"Under the current grant, we have continued **to improve** and extend **the original four courses**, *completed additional courses in S and F-I and made significant progress in completing course development in B, C, CA, empirical research methods, F-II, ME, P and advanced ST."*
"Issue: <u>Technical staff</u> *also changed"*	<u>"Technological support</u> for PQR *was transferred from the Web Content Coordinator to the Web Support Technician early in the Continuation Grant period."*

We calculated the percentage of the Annotation Template sentences that, according to our criteria, correspond to sentences in the reports, and we found that this percentage was 88%. The remaining 12% of the Annotation Template sentences are synthesized from the wider content of the report, and cannot be linked to particular sentences.

This high percentage indicates that human annotators synthesize relatively few times the contents of the project reports, and in the overwhelming majority of cases they judge that the original wording is sufficiently synthetic and self-contained. Thus in this aspect human and machine annotation are similar to a significant extent. Supposing that human annotation is effective in the sense-making activity, this high percentage of the corresponding sentences can justify a role for machine annotation for sense-making.

In order to get a more nuanced comparison in the cases when the sentences in the Annotation Template correspond to (meaningful and relevant units of) sentences in the project report, we measured the similarities and differences between them. We calculated the percentage of each of the three kinds of correspondence within the corresponding sentences. The unit of the comparison is the corresponding meaningful and relevant unit.

We found that 67% of the corresponding units are identical, 19% are synonymous or paraphrases and 14% are implications. We observe that the majority of the similarity is identity.

These measures reveal that the human annotators did use the original text to a great extent almost in its original form without synthesizing the contents. The results provide an additional demonstration of a potentially relevant role that machine annotation can play in the sense-making process.

However, despite the relatively great similarity between the original sentences and the sentences written by the analysts, it is important to note that the analysts do make changes—even if they are minor—in order to render the Annotation Template sentences self-contained. It is these changes that prepare the sentences for higher-level sense-making operations. We plan to carry out further studies to analyze these changes in order to suggest ways to accommodate the original sentences, which are not self-contained since they are embedded in their textual context, for sense-making operations.

Is there a latent correlation between the Annotation Template fields and the rhetorical functions?

According to the correspondence defined in point 2, we found that 62% of the sentences in the reports which could be associated with sentences in the Annotation Template convey rhetorical functions as they are defined in the XIP analyzer. This result demonstrates that the approach of detecting summary and problem sentences does cover a significant percentage of the sentences that appear in the Annotation Templates and thus the presentation of these sentences to the annotators would be of considerable help.

How can we evaluate machine-annotated sentences that do not correspond to sentences in the Annotation Template?

Further work is required to answer this question. The methodology will involve human analysts in evaluating the remaining 38% of machine-annotated sentences for their utility in synthesizing the results of the project reports. To the degree that XIP is judged to have highlighted important portions of text that no human analyst used, this will constitute evidence of further added value from machine annotation. However, as noted above, there is intrinsic variability in human annotation of this sort, which requires significant interpretation of the text.

9. Discussion and future work

This journal special issue invited contributions on a number of questions. The work reported here enhances our understanding of several of these, which we use to structure our concluding reflections.

What defines the forms of CI that are being studied or supported in the organization? How are they different from other human activities and, more specifically, from similar forms of CI observed in the wild?

As a conceptual contribution, we have motivated *Contested Collective Intelligence* as a significant and distinctive subset of the broader space of possibilities for conceiving and designing organisational CI. However, we have not made any assumptions that restrict CCI to formal organisations; we see it as applicable to any networked collective engaged in knowledge and evidence building. Research in computer-support for sensemaking, discourse, and annotation has motivated a conceptual model (Figures 1 and 2), to address the requirements for a CCI sociotechnical infrastructure.

What is the degree of domain modelling that the tools need?

We do not require a taxonomy, ontology or other formalization of domain-specific knowledge (such as the organisational structure, or its field of business). Rather, we model the ways in which stakeholders make and contest claims about these worlds, through XIP's use of rhetorical markers in naturally occurring prose, and provide an (user editable) range of ways for stakeholders to make meaningful moves via Cohere's hypertext annotation and knowledge mapping interface.

What mix of research methods are suitable for CI research and design?

We have combined an analytical approach with a case study. The analytical approach has been firstly to *characterise a distinctive class of organisational contexts* (in our case, those in which knowledge is contested, or in which stakeholders must engage in sensemaking to construct plausible narratives about past, present and future worlds). Secondly, this motivates the case for defining a *distinctive subset of CI* (which we call CCI), to *support these important characteristics*, which are not of focal interest to other forms of CI. Thirdly, we have proposed *specific technological vehicles* for implementing CCI (hybrid human plus machine annotation focused on the discourse moves that signal substantive contributions in a contested knowledge space).

The case study motivated a *proof of concept design*, and *empirical data analysis*. We converted XIP's output into Cohere annotations and networks, providing a demonstration of an integrated platform and user experience for interacting with the materials. We analysed the human/machine annotation sets using data from human analysts engaged in an authentic task. Analysts worked independently, and machine annotation was conducted independently from this, in order to facilitate comparison. The data analysis combined quantitative summary statistics with qualitative comparisons of annotation similarity.

What visualizations and abstractions can help to monitor and make sense of the activities of others?

This paper has illustrated in passing, but not focused on, the annotation interface, visualizations, conceptual model, and other services provided by Cohere. These have been documented elsewhere (Buckingham Shum 2008), and prior work has conducted user studies (Uren et al. 2006; Sereno et al. 2007).

The core of the argument has, however, focused on the importance of a particular kind of "abstraction" for making sense of others' activities, namely, how one can model, detect, and render one's own insights, and those of others, when making sense of a contested knowledge space. The tools described here, and the growing number of other platforms for structured deliberation[9], provide a new class of searching and alerting services that other abstractions cannot deliver.[9]

How do factors such as trust … affect information and activity flows in organizations; how can they be 'designed in' CI tools?

It took analysts 1–2 hours to read and annotate a project report, while it took XIP a matter of seconds, which raises intriguing questions around the nature of human and machine annotation, and questions of trustworthiness. A promising finding was that key contributions of relevance to CCI were effectively "announced" by documents' authors with explicit rhetorical moves, which both human analysts and XIP could readily identify. Since working with contested knowledge is at the heart of CCI, the evidence that automatic detection of contrasting ideas in texts is possible through rhetorical discourse analysis is progress towards the effective use of automatic discourse analysis in the CCI framework.

Projecting forward to future scenarios, under the typical conditions in which time is constrained, document resources are huge, and focused human attention is the scarcest resource, the role of machine annotation may be to assist and enhance reflective reading and understanding of documents, drawing attention cost effectively and in real time, to key passages where there appear to be making significant rhetorical moves such as mentioning key problems, gaps in knowledge, and contrasting ideas. Human annotation effort can then attend to higher-level activities such as abstracting, contextualizing and summarizing, and important social interactions to share and debate interpretations. This work suggests that, methodologically, mixed/initiative approaches are to be favored for the design of CCI infrastructures.

Even with the Annotation Template, it was clear that a distinctive feature of human annotation is the inherent variety that results from the unique connections that analysts make when they encounter a text. Humans display a unique capability to paraphrase ideas and make innovative new connections, which are critical to sensemaking, since they bring elements that machines currently lack: rich personal experience, critical eye, abstraction and synthesis. However, human annotations introduce biases on document analysis, since it is difficult to isolate how the analyst's personal perspective informs what they say, and what is extracted from the document. In this respect machine analysis provides results that are more faithful to the source document, although in this study, XIP also generated a much larger number of annotations, not all of which are useful, and which need to be appropriately filtered.

Given the conceptual foundations and initial evidence reported in this paper, future work will be deploying the prototype platform in authentic testbeds. The human annotation

[9] For examples of the range structured deliberation platforms which deploy models of dialogue and argumentation to promote collective intelligence, see *Online Deliberation: Emerging Tools 2010*: http://olnet.org/odet2010 and ESSENCE tools http://events.kmi.open.ac.uk/essence/tools. Gurkan, *et al.* (2010) also report field trial evaluations of a structured discussion platform which reflects the CCI concerns set out in this paper.

release of Cohere is already being deployed in a range of domains,[10] to which we would now like to add XIP. The next phase will enable us to begin answering more ambitious questions around the impact on collectives:

- In what contexts are readers keen to read annotated texts, versus the original clean text?
- To what extent do annotations influence the reading experience, and readers' interpretations?
- To what extent do readers value and trust other peoples' interpretations, and machine annotations?
- Do readers come to trust annotated documents enough to neglect full reading of the original text?
- What factors influence users to move from reading to active participation, engaging in knowledge-building discourse via annotation and connection-making?

Our view is that as machines 'earn' human trust through consistent and transparent performance, people will come to entrust the detection of certain classes of knowledge claims and citations to automated annotation. However, from a sensemaking/CCI perspective there will always remain a significant, and in our view critical, dimension of human interpretation. It is vital to the creative process that people read new meanings into documents that are not expressed in the text, and make new connections that derive from their unique histories, both personal and collective. Moreover, when we consider the political dimensions that are typically woven around organisational dilemmas, we are (at least currently) at the limits of what automated analysis can contribute. When tacit knowledge underpins important social dynamics, the human crafting of interpretive layers remains critical.

Acknowledgements

Cohere is being developed as part of the OLnet Project (http://olnet.org) funded by The William and Flora Hewlett Foundation. This work was conducted as part of an OLnet Visiting Fellowship for Ágnes Sándor at the Open University. Cohere uses the open source Prefuse visualization code from PARC: http://prefuse.org. The authors also thank the anonymous referees for their thorough and helpful reviews.

[10] e.g. Learning Sciences http://olnet.org/node/610, Open Educational Resources http://ci.olnet.org, and Climate Change

References

Aït-Mokhtar, S., Chanod, J. P., & Roux, C. (2002). Robustness beyond shallowness: incremental dependency parsing. *Natural Language Engineering*, 8(2/3), 121–144.

Andriessen, J., Baker, M., & Suthers, D. (2003). *Arguing to learn: Confronting cognitions in computer-supported collaborative learning environments* (Eds.). Kluwer: Dordrecht

Birnbaum, L., Horvitz, E., Kurlander, D., Lieberman, H., Marks, J., & Roth, S. (1996). Compelling intelligent user interfaces: How much AI?, *Proceedings ACM International Conference on Intelligent Interfaces*, Orlando, FL, January 1996. ACM Press: NY

Brown, A. L., Bransford, R. A., Ferraraand, R. A., & Campione, J. C. (1983). Learning, remembering, and understanding. In J. H. Flavell & E. H. Markman (Eds.), *Handbook of child psychology: Cognitive development (vol. 3).* New York: Wiley.

Browning, L., & Boudès, T. (2005). The use of narrative to understand and respond to complexity: a comparative analysis of the Cynefin and Weickian models. *Emergence: Complexity & Organization—An International Transdisciplinary Journal of Complex Social Systems*, 7(3–4), 32–39.

Buckingham Shum, S. (2003). The roots of computer supported argument visualization. In P. Kirschner, S. Buckingham Shum, & C. Carr (Eds.), *Visualizing argumentation* (pp. 3–24). London: Springer.

Buckingham Shum, S. (2008). Cohere: Towards Web 2.0 argumentation. *2nd International Conference on Computational Models of Argument*,28–30 May 2008, Toulouse. IOS Press: Amsterdam.

Buckingham Shum, S., Maclean, A., Bellotti, V. M., & Hammond, N. V. (1997). Graphical argumentation and design cognition. *Human-Computer Interaction*, 12(3), 267–300.

Buckingham Shum, S., Selvin, A., Sierhuis, M., Conklin, J., Haley, C., & Nuseibeh, B. (2006). Hypermedia support for argumentation-based rationale: 15 years on from gIBIS and QOC. In A. Dutoit, R. McCall, I. Mistrik, & B. Paech (Eds.), *Rationale management in software engineering* (pp. 111–132). Berlin: Springer.

Conklin, J., & Begeman, M. L. (1988). gIBIS: a hypertext tool for exploratory policy discussion. *ACM Transactions on Office Information Systems*, 4(6), 303–331.

Convertino, G., Billman, D., Pirolli, P., Massar, J. P., & Shrager, J. (2008). The CACHE Study: group effects in computer-supported collaborative analysis. *Computer Supported Cooperative Work*, 17, 353–393.

De Liddo, A., & Buckingham Shum, S. (2010). Cohere: A prototype for contested collective intelligence. *Workshop on Collective Intelligence in Organizations: Toward a Research*

Agenda, ACM Conference on Computer Supported Cooperative Work, Feb. 6–10, 2010, Savannah GA, USA. Available as ePrint: http://oro.open.ac.uk/19554.

De Waard, A., S. Buckingham Shum, A. Carusi, J. Park, M. Samwald, & A. Sándor (2009). Hypotheses, evidence and relationships: The HypER approach for representing scientific knowledge claims. *Workshop on Semantic Web Applications in Scientific Discourse*, 8th International Semantic Web Conference. LNCS, Springer Verlag: Berlin, 26 Oct 2009, Washington DC.

Dervin, B., & Naumer, C. (2009). Sense-making. In S. W. Littlejohn & K. A. Foss (Eds.), *Encyclopedia of communication theory* (pp. 876–880). Los Angeles: Sage.

Engelbart, D. C. (1963). A conceptual framework for the augmentation of man's intellect, in *Vistas in Information Handling*, P. Howerton and Weeks, Editors. 1963, Spartan Books: Washington, DC: London. p. 1–29.

Ghosh, A. (2004). Learning in strategic alliances: a Vygotskian perspective. *The Learning Organization*, 11(4/5), 302–311.

Goodman, N. (1986). Mathematics as an objective science. In T. Tymocyko (Ed.), *New directions in the philosophy of mathematics* (pp. 79–94). Boston: Birkhauser.

Gurkan, A., Iandoli, L., Klein, M., & Zollo, G. (2010). Mediating debate through on-line large-scale argumentation: evidence from the field. *Information Sciences*, 180, 3686–3702.

Hagel, J. III, Seely Brown, J., & Davison, L. (2010). *The power of pull: How small moves, smartly made, can set big things in motion*. Basic Books

Heuer, R. (1999). *The psychology of intelligence analysis*. Washington, DC: Center for the Study of Intelligence, Central Intelligence Agency.

Hong, L., Chi, E. H., Budiu, R., Pirolli, P., & Nelson, L. (2008): SparTag.us: A low cost tagging system for foraging of web content. In: *Proc. AVI 2008*, pp. 65–72. ACM, New York.

Horvitz, E. (1999). Principles of mixed-initiative user interfaces, In *Proceedings of the ACM Conference on Human Factors in Computing Systems*. (Pittsburgh, Pennsylvania), pp. 159-166. ACM, New York.

Kalnikaité, V., & Whittaker, S. (2008). Social summarization: does social feedback improve access to speech data? In *Proceedings of conference on computer supported co-operative work*, ACM Press, New York, pp 9–12.

Klein, G., Moon, B., & Hoffman, R. F. (2006). Making sense of sensemaking 1: alternative perspectives. *IEEE Intelligent Systems*, 21(4), 70–73.

Kurtz, C., & Snowden, D. (2003). The new dynamics of strategy: sense-making in a complex-complicated world. *IBM Systems Journal*, 42(3), 462–83.

Kong, N., Hanrahan, B., Weksteen, T., Convertino, G., & Chi E. H. (2011).: VisualWikiCurator: Human and Machine Intelligence for Organizing Wiki Content. In: *Proc. IUI2011*.

Levy, D. M., & Marshall, C. C. (1995). Going digital: a look at assumptions underlying digital libraries. *Communications of the ACM*, 38(4), 77–84.

Lin, X., Hmelo, C., Kinzer, C. K., & Secules, T. J. (1999). Designing technology to support reflection. *Educational Technology Research and Development*, 47(3), 43–62.

Lowrance, J., Harrison, I., Rodriguez, A., Yeh, E., Boyce, T., Murdock, J., Thomere, J., & Murray, K. (2008). Template-based structured argumentation. In A. Okada, S. Buckingham Shum, & T. Sherborne (Eds.), *Knowledge cartography: Software tools and mapping techniques*. London: Springer.

Malone, T. W., Laubacher, R., & Dellarocas, C. N. (2009). Harnessing crowds: Mapping the genome of collective intelligence. *MIT Sloan Research Paper No. 4732–09*. Available at SSRN: http://ssrn.com/abstract=1381502.

Mercer, N. (2004). Sociocultural discourse analysis: analysing classroom talk as a social mode of thinking. *Journal of Applied Linguistics*, 1(2), 137–168.

Okada, A., Buckingham Shum, S., & Sherborne, T. (2008). *Knowledge cartography: Software tools and mapping techniques*. London: Springer.

Pea, R. D. (1993). Learning scientific concepts through material and social activities: conversational analysis meets conceptual change. *Educational Psychologist*, 28, 265–277.

Pirolli, P., & Card, S. (1995) The sensemaking process and leverage points for analyst technology as identified through cognitive task analysis. *Proceedings of 2005 International Conference on Intelligence Analysis*,2–4

Pirolli, P., & Russell, D. (2008). Call for submissions to special issue on sensemaking, *Human-Computer Interaction*. http://www.tandf.co.uk/journals/cfp/hhcicfp_sp1.pdf

Rich, P. J., & Hannafin, M. (2009). Video annotation tools: technologies to scaffold, structure, and transform teacher reflection. *Journal of Teacher Education*, 60(1), 52–67.

Rittel, H., & Webber, M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, 4, 155–169.

Russell, D. M., Stefik, M. J., Pirolli, P., & Card, S. K. (1993). The cost structure of sensemaking. *Proceedings of InterCHI'93*, pp. 269–276. Amsterdam: Association for Computing Machinery.

Sándor, Á. (2007). Modeling metadiscourse conveying the author's rhetorical strategy in biomedical research abstracts. *Revue Française de Linguistique Appliquée*, 200(2), 97–109.

Sándor, Á., & Vorndran, A. (2010), Extracting relevant messages from social science research papers for improving retevance of retrieval. *Workshop on Natural Language Processing Tools Applied to Discourse Analysis in Psychology*, Buenos Aires, 10–14 May 2010.

Scaife, M., & Rogers, Y. (1996). External cognition: how do graphical representations work? *International Journal of Human-Computer Studies*, 45, 185–213.

Scardamalia, M., & Bereiter, C. (1994). Computer support for knowledge-building communities. *The Journal of the Learning Sciences*, 3, 265–283.

Scardamalia, M. (2002). Collective cognitive responsibility for the advancement of knowledge. In B. Smith (Ed.), *Liberal education in a knowledge society* (pp. 67–98). Chicago: Open Court.

Selvin, A. (2011). Making representations matter: Understanding practitioner experience in participatory sensemaking. *Unpublished Doctoral Dissertation*, Knowledge Media Institute, The Open University, UK

Sellen, A., & Harper, R. (2003). *The myth of the paperless office*. MIT Press

Sereno, B., Buckingham Shum, S., & Motta, E. (2007). Formalization, user strategy and interaction design: Users' behaviour with discourse tagging semantics. *Workshop on Social and Collaborative Construction of Structured Knowledge*, International World Wide Web 16th Conference (WWW 2007), Banff, AB, Canada; 8–12 May 2007.

Shrager, J., Billman, D. O., Convertino, G., Massar, J. P., & Pirolli, P. L. (2010). Soccer science and the Bayes community: exploring the cognitive implications of modern scientific communication. *topiCS -Topics in Cognitive Science*, 2(1), 53–72.

Smallman, H. S. (2008). JIGSAW-joint intelligence graphical situation awareness web for collaborative intelligence analysis. In M. P. Letsky, N. Warner, S. Fiore, & C. A. P. Smith (Eds.), *Macrocognition in teams: Theories and methodologies* (pp. 321–337). Hampshire, England: Ashgate Publishing.

Snowden, D. J., & Boone, M. E. (2007). Leader's framework for decision making. *Harvard Business Review*, Nov 01, 2007.

Tecuci, G., Boicu, M., & Cox, M. T. (2007). Seven aspects of mixed-initiative reasoning: an introduction to this special issue on mixed-initiative assistants. *AI Magazine*, 28(2).

Uren, V., Buckingham Shum, S., Li, G., & Bachler, M. (2006). Sensemaking tools for understanding research literatures: design, implementation and user evaluation. *International Journal of Human Computer Studies*, 64(5), 420–445.

van Gelder, T. J. (2002). Enhancing Deliberation Through Computer-Supported Argument Visualization. In P. Kirschner, S. Buckingham Shum, & C. Carr (Eds.), *Visualizing argumentation: software tools for collaborative and educational sense-making* (pp. 97–115). London: Springer.

Weick, K. E. (1995). *Sensemaking in Organizations*. Thousand Oaks, CA: Sage Publications.

Weick, K. E. (2006). Faith, evidence, and action: better guesses in an unknowable world. *Organization Studies*, 27, 1723–1736.