KNOWLEDGE MEDIA
KMi
INSTITUTE

# Interfaces for Capturing Interpretations of Research Literature

*Victoria Uren, Bertrand Sereno,*
*Simon Buckingham Shum & Gangmin Li*

KMI-TR-130

September, 2003

www/kmi.open.ac.uk/publications/papers/kmi-tr-130.pdf

The Open University

# Interfaces for Capturing Interpretations of Research Literature

**Victoria Uren, Bertrand Sereno, Simon Buckingham Shum & Gangmin Li**
Knowledge Media Institute, The Open University
Milton Keynes, MK7 6AA, United Kingdom
v.s.uren;s.buckingham.shum;b.sereno;g.li@open.ac.uk

## ABSTRACT
The ClaiMaker collaborative sense-making and annotation tools allow single users and groups to build and query hypertextual argument maps of research literatures. We describe the discourse ontology used by the system, and four design principles that were followed to make it usable for non-knowledge engineers. We present several generations of capture interfaces showing how they are evolving to make ClaiMaker more accessible for novice users.

## Keywords
Knowledge capture user interfaces, Interface evolution, Semantic annotation, Cognitive support, Network models

## INTRODUCTION AND MOTIVATION
Researchers are interested in questions such as: Where did this idea come from? What kind of evidence supports it, and challenges it? How does the expert community perceive this data, model or theory? These are questions of interpretation. Unfortunately, current e-Science infrastructures have no model of scholarly discourse, that is, 'what counts' as a principled contribution or argument in the interpretation of research results. The Scholarly Ontologies project is developing a system, called ClaiMaker, to support scholarly interpretation and discourse, investigating the practicality of annotating conventional documents with explicit argument maps which form an interpretational layer over raw resources such as document or dataset archives (1).

Consider the following scenarios which show how an argument mapping system could augment research activities:

- Collaborative work - a team of researchers from several organizations are collaborating on an ongoing project. When a researcher reads an article that he believes is pertinent he can model the key points in a conceptual model shared by the whole group. The model allows researchers to pool the results of their reading, and to alert each other to new results. In this way, it assists collaborative sense-making and records the evolution of ideas over the history of the project, thus facilitating the preparation of reports. New additions to the model alert other team members to interesting documents.
- Reviewing the literature - A postgraduate student is reviewing the literature to identify a niche. As she explores the literature she notes key questions and problems, and sees who is addressing them and what answers have been forthcoming. The object is to identify unanswered questions. The tool should allow the student to build structures representing questions and answers, problems and solutions which link directly to the reference details of papers. The final model helps the student structure her literature review and can be extended during her ongoing research.

In this paper we introduce the argumentation representation scheme focusing on the aspects of it that have a bearing on its usability. We report on a series of capture interfaces showing how they are evolving to give users cognitive support for the modeling process.

## MODELLING ARGUMENTATION
A representation scheme for the arguments in papers needs to achieve a fine balance between completeness and usability. It would be possible to produce an elegant formal ontology that could perform logic-driven operations of the type familiar in many AI systems. However, if the database is to be populated by domain experts from fields outside knowledge engineering it seems implausible that a critical mass of readers of research papers would feel inclined to learn such a scheme or have the confidence to publish the argument maps they built using it. Conversely, a weak scheme could not deliver sufficient services to make it worth the readers' while to use it. In both the ontology design and the development of interfaces we have been guided by the findings of Shipman & Marshall:

> "Users are hesitant about formalization because of a fear of prematurely committing to a specific perspective on their tasks; this may be especially true in a collaborative setting, where people must agree on an appropriate formalism" (2)

The ontology and representation scheme have been described in our previous work (3)(4). In summary, ClaiMaker models are directed graphs in which Concepts (or Sets of Concepts) form the nodes, and the links drawn from an ontology of discourse relations Within the ontology, relations are classified into groups with similar rhetorical implications: Supports/Challenges, Problem-related, Taxonomic, Causality, Similarity, and General (e.g. proves is a Supports/Challenges link). Each relation belongs to exactly one group. Each relation is assigned a polarity which indicates whether it has positive or other negative implications (e.g. the label *proves* has positive polarity whereas *refutes* has negative polarity; it implies *dis*proof). Each relation is also assigned a weight (high or low) which indicates how forceful it is (e.g. *refutes* is more forceful than *disagreesWith*). Relations also have a natural language link to identify them.

We appreciate that the formality of the above description is likely to be intimidating to the average novice. ClaiMaker is intended for use by domain experts and not by knowledge engineers. Therefore we have tried to hide some of the formality from the users through the interface, and only to enforce those parts of it which are essential. In doing this we have followed four principles, which we elaborate below:

- do not enforce granularity
- use familiar natural language
- do not attempt truth maintenance
- models must support services

Building models in ClaiMaker complements the familiar scholarly practice of reading and making sense of research articles. One aspect of such reading is identifying the key ideas in a paper. When reading hard copy many scholars annotate key points as they read, for example by circling or highlighting chunks of text. In ClaiMaker these chunks could form the basis of Concepts. These are not, in the formal knowledge engineering sense, atomic concepts. To illustrate, in the Shipman & Marshall quote above *"formalism"* is an atomic concept. ClaiMaker concepts are chunks of text that describe the objects of enquiry – problems, theories, pieces of evidence, hypotheses etc. To illustrate from the same quote, *"Users of collaborative systems distrust premature commitment"* might be one way of summarizing the problem. There is nothing in the system that prevents users creating atomic concepts if they need or wish to, but there is also nothing to enforce it. The user is left free to create concepts at the level of granularity that suits their present purpose and can refine them later if it becomes necessary. This is the first of our principles: the granularity of models is not enforced.

The next level of sense-making comes when the reader starts to see the connections between the key points in the paper they are currently reading, and their connections to points made by other articles. In ClaiMaker this stage is mirrored by the creation of Claims. Formally speaking, a Claim is a triple of two Concepts joined by a typed link. From the user's point of view, making a Claim consists of identifying the two Chunks of text he wishes to join and selecting a suitable link from the list of natural language link labels. The precise wording of the labels can be changed to suit the "dialect" of the community (this job is best done by a knowledge engineer to ensure that the words match the parameters of the discourse ontology). This means that users are picking their labels from a list which is couched in terms that they recognize rather than a list of formal terms which, while they may have very precise meanings for logicians, are not necessarily understood in the same way by people who do not have a training in logic. This is the second principle: use familiar natural language.

The discourse ontology provides a common language to use when making claims. It differs from most ontologies because it must accommodate more than one view of the data, because researchers often take different or even conflicting positions. To give an accurate picture of a literature, argument maps must contain structures that contradict each other. This illustrates our third principle: do not attempt truth maintenance.

The fourth principle, models must support services, is discussed in our other work (5) (4), where we show how elements of the ontology can be used to implement semantic search services for ClaiMaker models. Even in the context of this paper on interfaces for capture it is still important to emphasize that unless services are provided that help users make sense of the literature they are modeling they will have no motivation for using the system. If we consider only straightforward search facilities, before novice users can start to build argument maps of research literatures they must first get an understanding of what kind of a model they will be building, its components, their level of granularity and so forth. Looking at examples is an obvious way for them to start to learn how to decompose text into Concepts, Claims and more complex structures. For experienced users adding to an existing knowledge base of argument maps, search is also an essential preliminary activity. They need to know what the knowledge base already contains on the topic of interest, and whether the particular paper they are looking at has existing structures associated with it that they could reuse, or even take issue with if they have a different interpretation.

## CAPTURE INTERFACES

Putting formality into the background does not resolve all possible difficulties. Readers still face conceptual challenges deciding how to build their maps. Supporting the conceptual processes of modeling is the domain of interface design. As the ClaiMaker prototype has been developed and we have learnt more about the problems users encounter with modeling we have evolved different interfaces for inputting and searching models. The first group of interfaces are for capturing maps: a basic forms-based interface and a plug-in for authors to produce concepts within a popular authoring environment. We then describe two refinements: a sketching interface and an interface based on text extraction techniques.

## Form Filling

The first version of ClaiMaker used forms with basic features such as keyboard input, text search and dropdown lists. Its aim was to allow the project team to start inputting data as quickly as possible in order to build a test collection that could be used for designing services. It took a stepwise approach to creating claim networks: first the user had to nominate the article they were modeling, then one form allowed her to create Concepts, another could be used to assemble Sets by searching for and selecting groups of Concepts, a series of other forms allowed claims to be made by selecting pre-existing Concepts and joining them (See Figure 1). Capture was broken down into subprocesses which meant that the user needed to understand the process as a whole in order to decide which step to take next, and also had to know where in the menu system the appropriate form was located.

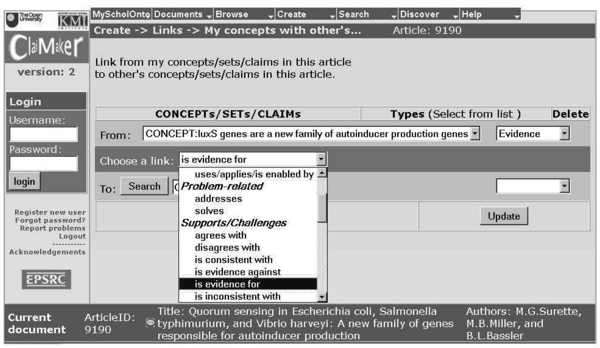


**Figure 1** Screen shot of the forms interface for creating a claim. The bottom bar gives details of the paper the reader is modeling. The user has already selected the concept to be linked *from* and given it the optional type "Evidence". She is currently selecting a link from the drop down list of options. The next step will be to select the search button to look for the third component of the Claim triple.

Although the power users on the project team did become reasonably fluent with the interface, even they had difficulty holding a gestalt view of the model in their heads as they went through the dissociated steps of building Concepts then assembling them into Claims. It was clear that some radical changes were needed to make capture interfaces better support the cognitive processes involved in modeling.

One approach that can give support to authors is to integrate the model capture process directly with the process of authoring papers, to minimise the delay between the expression of the idea in conventional prose, and its formalization. As a first step we have begun work on a Microsoft Word plug-in (see Figure 2) that allows authors to launch direct from the Word toolbar a 'semantic annotation' form to enter the major types of Concepts in a paper as they write it. These can be classified in response to some prompts: *Problem? Contributions? Uses/Applies? Improves on? Contrasts/Critiques?*. These prompts foreground the most important relational links in the ontology for summarising an article's contribution, in other words, 'promoting' them from the longer menu of relational types available in the more complex forms interface (Figure 1), and turning them into questions. Once the concepts have been saved (as an XML file), the idea is that the Concepts will then be imported into ClaiMaker and used as a basis for further Claim building.

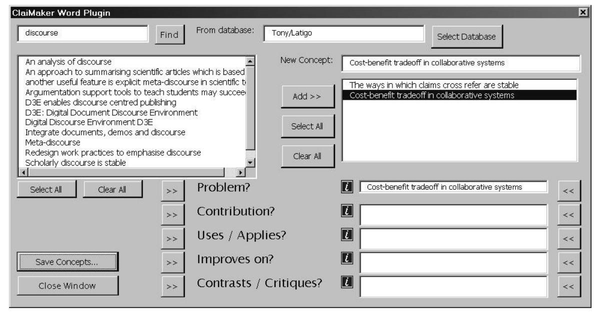


**Figure 2**. ClaiMaker Word plug-in. Existing Concepts on the web server can be searched and displayed in the panel top left. New concepts are displayed on the right and can be assigned types using the five prompts in the lower part of the screen:

## Sketching

In order to overcome the problems of holding complex models in memory the team found themselves resorting to pen and paper for sketching out drafts of argument maps. In part this was because the form-filling interface had no correction facility (this was to prevent users from deleting or altering the text of a Concept which they no longer liked but which had meanwhile been included in someone else's model), but it was mainly driven by a desire to consolidate the reader's own interpretation before committing it to the knowledge base. In the terms of Shipman & Marshall's analysis the interface was "enforcing premature structure" (2), by making the users commit a structure before they had tested its validity in the evolving map.

It is clear that a new interface should offer better cognitive support for the process of sketching draft maps and for seeing new structures in context before committing them to the knowledge base.

We tested the sketching concept using the Compendium sense-making tool, which has features for creating Concept networks that are not unlike those in Claimaker (6). Producing valid maps in Compendium required users to comply with some conventions (see Figure 3). For example, Concepts and Claims had to be associated with a document, links had to be drawn from the ontology of discourse relations, and if a Claim used an existing Concept its ID number had to be tagged.

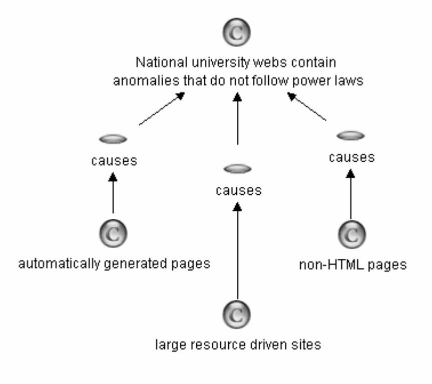


**Figure 3** Sketching ClaiMaker models using Compendium, with Concepts represented circles and link types as ellipses This sketch is from a paper by Thelwall & Wilkinson (7).

A script was devised, using these conventions, that could take Compendium structures and import them into the main database, checking for duplicate node labels and illegal structures in the process. This proved that the sketching approach was feasible. However, it was also tedious, as the checking routines threw up significant numbers of errors and warnings. Warnings included duplicate Concepts in the database which it wished the user to confirm were identical or to change. Some errors were simple, e.g. misspelling of a link label. Others were structural, e.g. putting the whole of a model for a paper as an element of a claim. It seemed that even our own team members, who had had the discipline of working within the constraints of the forms interface got inventive as soon as those constraints were relaxed.

It seems that, while we do not want the sketching interface to enforce premature structure, we do want it to give positive assistance to the user to build models that are valid and can be painlessly imported into the ClaiMaker database. The forms interface enforced legal structures because the range of operations on each form was limited to legal actions and invalid inputs such as incomplete Claims were discarded. As we continue with our development of a ClaiMaker-specific sketching interface we need to tackle the question of how it can communicate to a user what a model ought to look like. One possibility, which we have described elsewhere (3), is to provide readers with claim-making templates for stereotypical 'genres' of paper.

## Text Analysis

The next interface tackles the "chunking" problem identified by Shipman & Marshall (2). This is the problem that causes beginners to ask what kind of things should be made into Concepts and how long they should be. This question does not have a simple answer because it depends on the reader's interpretation of the paper, and therefore, the use of the original text as a supporting device to formulate claims is not going to be straightforward. How do we reconcile the automatic analysis of a text, which would yield a *unique* 'reading', with the diversity of opinions we want to capture?

The assumption underlying our approach is that it is the *argument* of the author that is going to be debated - the hypothesis, assumption, methodology and results. Our text-analysis based approach relies on three elements:

- Identification of the areas where the author presents and defends her argument, combined with approaches to break up the text into *potential* concepts
- Provision of additional services to support collaboration within a group of readers / annotators
- Provision of an interface to support the capture of claims

We believe the reader could be directed towards a number of relevant locations and/or concepts. We should stress that we do not want to summarize a scholarly document or reduce it to a set of text strings. Indeed, any particular aspect of a document might be of interest to at least one annotator. By emphasizing the areas where the author explains her position, we aim to reduce the cognitive load, while still retaining full access to the remainder of the document.

**Enhancing a document.** The first step of our approach is to enhance the document with hyperlinks to and from multiple locations within it. Authors have to defend their position and their contributions, and relate them (through praise or criticism) to the positions of their colleagues (8). We believe that the ability to guess the role played by a sentence in this defence, using text analysis methods, provides a valuable resource in the task of interpretation, which can be seen as the task of positioning oneself with respect to the author's assertions.

We use text patterns that can be consistently associated with certain kinds of assertion to identify and categorize statements that signal stages of the argument. For example, our discourse ontology has natural language labels, which can be changed to fit the dialect of the domain, so the simplest approach is to identify locations where the labels appear. This gives us an indication of where (and how) the author defends her argument. Another category of interest is statements about contributions made by the authors. These are identified using references to the document itself (e.g. "Section 2 describes...") and references to the authors (e.g. "We have proposed..."). Once patterns such as these are combined with approaches to identify potential components of Concepts, like named-entity recognition, or more interestingly, noun-group identification, the system can propose a number of elements ready to use as a part of a Claim, while still leaving the reader free to edit them.

Related approaches are found, for instance, in the Create A Research Space model (8) where a number of linguistic cues (verbs, adverbs, citation signals …) are provided to assist the recognition of author intentions. A revised approach is explained by Teufel (9), where the role played by a sentence, (e.g. introducing the authors' work, providing background information, or supporting a cited work) is guessed from a number of annotated examples described in terms of an exhaustive range of features including sentence contents or position in the document.

To complement this approach, one could look at further means to enrich a document, for instance the inclusion of hyperlinks between topically coherent passages (10) or between a term and its definition (11).

**Supporting collaboration.** The second step of our approach aims at incorporating and making use of the Claims encoded by fellow readers, and the Concepts they connect. A list of Concepts previously created for the document in hand allows one to see how they have been defined, how they are related to other Concepts, and eventually, to decide (or not) to reuse them. Similarly, displaying the position defended by fellow annotators, as a set of Claims, can show what has been said about the document.

**Providing an interface.** Since our ultimate concern is the capture of structures in a knowledge base, we also turned to ontology-supported document annotation tools. They typically display side by side the original document and a form to input an instance of a class (12). Our tool would provide a similar functionality, potentially reusing the form-based interface described earlier.

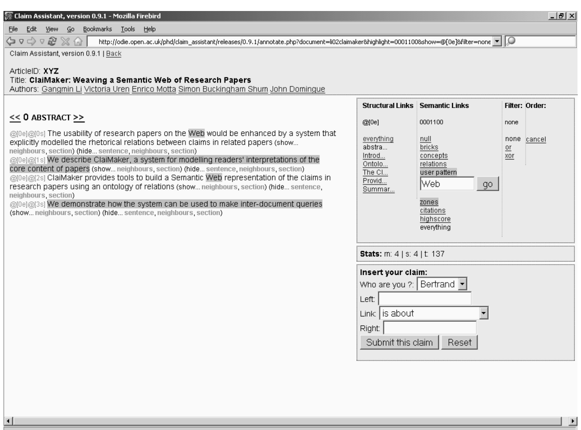


**Figure 4** Snapshot of the text analysis based tool, which separates the screen into three panels: a document panel containing the original document on the left side, a hyperlink highlighting control panel on the upper right side, and a form panel to input one's claims on the bottom right.

The first prototype of our text-analysis based tool to insert Claims (Figure 4) starts to implement this three-fold approach. A scholarly document is enriched by hyperlinks to areas containing a perfect match of an instance of the discourse ontology label and the areas deemed to describe the author's contributions.

The hyperlink highlighting control panel allows the user to "combine" links through an on/off switching mechanism that highlights text spans in different colors. By filtering the areas of the document matching several criteria one can, for example, look for instances of the string *ScholOnto* in sentences describing authors' self-declared contributions.

Finally, the reader can build her own representation of the document, by displaying or hiding sentences and/or sections. This last feature allows the creation of a personalized view of the document, displaying as much information as needed to build and submit a ScholOnto claim to the knowledge base.

# EXAMPLE

We now turn to an example showing how these interfaces could be used together to help one move from the contents of a scholarly document to a set of ScholOnto claims. In this example, we choose to use the text-analysis based interface to assist the discovery of potentially interesting elements in the text, and the mapping interface to refine the claims. Figure 5 shows how the interfaces interact:

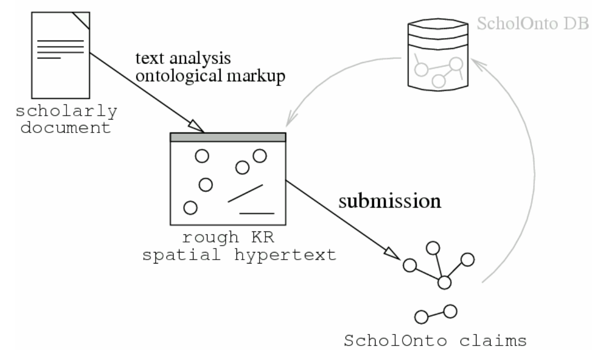


**Figure 5** Moving from a scholarly document to a set of ScholOnto claims via a two-step process.

The text-analysis interface guides the annotator towards sources of information in the original document. In the example we gave earlier, sentences describing the author's work could be reached through a set of hyperlinks. Figure 4 shows an abstract of an article with the authors'contributions highlighted. Two sentences ("*We describe ClaiMaker, a system for modeling readers' interpretations of the core contents of papers*" and "*We demonstrate how the system can be used to make inter-document queries*") have been automatically identified because they explicitly state what the authors are going to describe and what it will allow them to do. The annotator can also access previously encoded concepts and claims. She creates her own view of the document, by keeping and highlighting some elements and discarding others

The next step is to create claims, by modifying, refining and organizing the highlighted elements. The sketching interface could help in this task. The elements could be exported and used to fill a blank sketching space. Figure 6 shows such a populated space. On the left side of the screen, we have from top to bottom a node representing the whole document, a question node *"What are the contributions of this document ?"* and tentative answers provided by sentences deemed to describe the authors' work. On the right side of the screen, a collection of nodes is automatically created, each representing a tentative concept found in the original text, or a concept identified by a fellow annotator, or a link to related work.

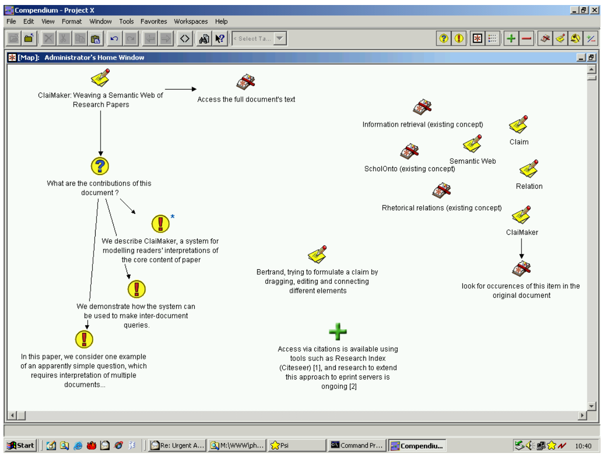


**Figure 6** The sketching interface populated by incorporating elements from the text-based interface.

The final task would be to modify and rearrange these elements into the claims the annotator wants to formulate, which would be submitted to the ScholOnto database.

## RELATED WORK

The Scholarly Ontologies approach shares some of the aims of annotation technologies. Ovsiannikov et al. (13) analyze common practices of traditional hand-written annotation and identify its primary uses as: "to remember, to think, to clarify and to share". They observe that the first three are predominant for traditional annotation which, with the exception of reviewing, is a largely private affair, but that sharing becomes more important for software annotation systems which facilitate collaborative annotation. However the decisive benefit of annotation technology over traditional annotation is searchability. This reinforces our view that developing the search interface and services of the ClaiMaker system is central to encouraging and supporting knowledge capture.

The TRELLIS system is a rare example of a system which adds a semantic element to annotation by linking statements drawn from web documents using a set of discourse, logical and temporal connectives (14). TRELLIS is designed to assist analysis of multiple documents, but does not consider multiple users collaborating, and does not use the semantic relations in automatic analysis of data.

The aspects of sharing and searching are prominent in collaborative Semantic Web annotation technologies, such as Annotea, being developed by the W3C (15). The Semantic Web approach to annotation regards it as searchable metadata stored on web servers with Xpointers to original documents. This approach is now being incorporated in applications such as management reporting (16).

Concept mapping tools for teaching sense-making and argument construction are well established. A sample of reports show it being used to promote understanding in sociology students (17), to develop legal reasoning skills (18), and to identify misconceptions about basic concepts held by trainee physics teachers (19). An overview of applications of argument mapping, including domains outside education, is provided by Kirschner et al. (20).

A more general interest in knowledge representations grounded in network structures is emerging. The Topic Map standard (21) is raising interest for knowledge management applications, and the RDF standard proposed by W3C can be used to encode concept maps (22).

Finally, Thagard's work (23) on modeling scientific revolutions complements our work. Using a knowledge representation scheme focused on the conceptual structures behind competing theories, he adds parameters to provide a quantitative indication of the 'explanatory coherence' of a given theory, given the available evidence and competing theories. Thagard's work contrasts with ours in its dependence on an expert modeler codifying theories at a finer granularity and with greater care than we can assume with our envisaged end-users. The target of his modeling is complementary in the sense that ClaiMaker's discourse ontology is designed to support the collaborative construction of claims – a form of computer-supported collaborative work – in contrast to the modeling of a well-understood debate, in which it is clear whether, for instance, a hypothesis has been refuted. ClaiMaker enables peers to contest this claim, rather than take it for granted. There is potential for integrating the two approaches.

## FUTURE WORK

The interfaces we present in this paper are being evolved to incorporate better cognitive support for the argument mapping process and to lower the learning barrier for novice users. The ClaiMaker system is a prototype under active development. Of the interfaces discussed here the forms-based system is available for interested parties to test (24), with a variety of analysis services available to interrogate claim structures (4, 5). The sketching tool is available as a standalone application (25), and is currently being integrated more tightly with ClaiMaker. The Claim Assistant tool and the Word plug-in are running prototypes, although in a preliminary state

The next step is to complete the development and user testing of the interfaces to determine their usability by novices. Then we intend to deploy the system in early adopter communities to determine the usefulness of ClaiMaker for tasks such as critical review and sense-making in research literatures.

## ACKNOWLEDGEMENTS
We gratefully acknowledge the support of the UK's EPSRC (Distributed Information Management Programme GR/N35885/01) in funding the Scholarly Ontologies Project. Thanks also to Tony Brush for design and implementation work on the ClaiMaker Word plug-in.

## REFERENCES
[1] Buckingham Shum, S., Motta., E., Domingue, J. (2000) ScholOnto: an ontology-based digital library server for research documents and discourse, International Journal on Digital Libraries 3, 237-248.

[2] Shipman, F.M. III, Marshall, Catherine C. (1999) Formality Considered Harmful: Experiences, Emerging Themes, and Directions on the Use of Formal Representations in Interactive Systems. Computer Supported Collaborative Work 8, 333-352.

[3] Buckingham Shum, S., Uren, V., Li, G., Domingue, J., Motta, E. (2003) Visualising inter-networked argumentation. In Visualizing Argumentation: Software Tools for Collaborative and Educational Sense-Making, ed. Kirschner, P. A., Buckingham Shum, S. and Carr, C. (Springer-Verlag, London), pp. 185-204.

[4] Uren, V., Buckingham Shum, S., Li, G., Domingue, J., Motta, E. (2003) Scholarly publishing and argument in hyperspace. In WWW2003, 12th Int. World Wide Web Conference (ACM Press, Budapest, Hungary), pp. 244-250.

[5] Li, G., Uren, V., Motta, E., Buckingham Shum, S., Domingue, J. (2002) ClaiMaker: weaving a semantic web of research papers. In ISWC2002, 1st International Semantic Web Conference, Sardinia).

[6] Conklin, J., Selvin, A. Buckingham Shum, S., Sierhuis, M. (2001) Facilitated Hypertext for Collective Sensemaking: 15 Years on from gIBIS. Technical Report TR Number 112 (Knowledge Media Institute, Milton Keynes, UK).

[7] Thelwall, M., Wilkinson, D. (2003) Graph structure in three national academic Webs: Power laws with anomalies. Journal of the American Society for Information Science and Technology 54, 706-712.

[8] Swales, J. M. (1990) Genre analysis: English in academic and research settings. Genre analysis: English in academic and research settings (CUP, Cambridge).

[9] Teufel, S. Moens, M. (2002) Summarizing scientific articles: experiments with relevance and rhetorical status. Computational linguistics 28.

[10] Hearst, M. A., Plaunt, C. (1993) Subtopic structuring for full-length document access. In Proceedings of the ACM SIGIR'93 Conference.

[11] Blustein, J. (2000) Automatically generated hypertext versions of scholarly articles and their evaluation, In Proceedings of the 11th ACM Hypertext confer-ence, pp. 201--210.

[12] Vargas-Vera M., Motta, E., Domingue J., Lanzoni M, Stutt A and Ciravegna F. (2002) MnM: Ontolpgy driven semi-automatic and automatic support for semantic markup. In Proceedings of the 13th International Conference on Knowledge Engineering and Management (EKAW 2002).

[13] Ovsiannikov, I.A., Arbib, M.A., Mcneill, T.H. (1999) Annotation technology. International Journal of Human-Computer Studies 50, 287-362.

[14] Gil, Y., and Ratnakar V. (2002) TRELLIS: an interactive tool for capturing information analysis and Deci-sion making. In EKAW 2002, LNAI 2473, pp. 37-42.

[15] Kahan, J., Koivunen, M., Prud'Hommeaux, E., Swick, R. (2001) Annotea: An open RDF infrastructure for shared Web annotations. In 10th International World Wide Web Conference (WWW2001), Hong Kong).

[16] Miles-Board, T., Carr, L, Kampa, S., Hall, W. (2003) Supporting management reporting: a writable web case study. In 12th Int. World Wide Wed Conference (ACM Press, Budapest), pp. 234-243.

[17] Trepagnier, B. (2002) Mapping sociological concepts, Teaching Sociology, 30, 108-119.

[18] Carr, C. S. (2003) Using computer supported argument vizualization to teach legal argumentation. In Visualizing argumentation: software tools for collaborative and educational sense-making, ed. P.A.Kirschner, S.J.Buckingham Shum, C.S.Carr (Springer-Verlag, London), pp. 75-96.

[19] Adamcyzk, P. Wilson, M. (1996) Using concept maps with trainee physics teachers. Physics Education 31, 374-381.

[20] Kirschner, P.A., Buckingham Shum, S.J., Carr, C.S. (2003) Visualizing argumentation: software tools for collaborative and educational sense-making (Springer Verlag, London).

[21] Pepper, S. (1999) Navigating haystacks and discovering needles: introducing the new topic map standard. Markup Languages Theory & Practice 1, 41-68.

[22] Corby, O., Dieng, R., Hebert, C., (2000) A Conceptual Graph Model for W3C Resource Description Framework. In Proceedings of International Conference on Conceptual Structures ICCS 2000, Darmstadt, Germany).

[23] Thagard, P. (1992) Conceptual Revolutions. New Jersey: Princeton University Press. ISBN: 0-691-02490-1

[24] ClaiMaker Sandpit http://claimaker.open.ac.uk/Sandpit/

[25] Compendium hypertext concept mapping tool: www.CompendiumInstitute.org