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Publishing, Interpreting and Negotiating Scholarly Hypertexts: Evolution of an Approach and Toolkit

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KMI-TR-57

December, 1997

Submitted for publication

[http://kmi.open.ac.uk/kmi-abstracts/kmi-tr-57-abstract.html].

Publishing, Interpreting and Negotiating Scholarly Hypertexts: Evolution of an Approach and Toolkit

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ABSTRACT
This paper describes the evolution of our approach to scholarly hypertext publishing, which is developing a social model of document usage that places particular emphasis on supporting the interpretation and negotiation of documents. The first part of the paper describes principles derived from hypertext research that underpin a toolkit called D3E which we use to publish an electronic journal. This provides a Web environment that tightly integrates publications with review discussion. In part two, we argue that forming and contesting perspectives are key processes that should be assisted by scholarly hypertexts. In the context of our e-journal, we analyse the representational requirements for hypertext support, and explore the expressive power of a semiformal document encoding scheme that expresses a publication's conceptual relationship to other documents. We conclude by discussing socio-technical issues that this work raises.

KEYWORDS: scholarly hypertext, argumentation, electronic journals, publishing, metadata, ontologies, WWW.

INTRODUCTION
The emergence of the World Wide Web has potentially far reaching implications for scholars, because documents mediate their everyday work. This observation is at one level banal and not particularly helpful: documents mediate the established work practices of every organisation. However, taking this simple observation as a point of departure, a detailed understanding of the work that documents support, the contexts in which they are embedded, and the processes that give them their true significance in the communities that read and write them, opens up a spectrum of possible uses for new technologies.

Brown and Duguid [4] contrast two models of document use: documents as darts and documents as a means of making and maintaining social groups. The 'darts' model refers to the notion of documents as a paper-based transport mechanism carrying pre-formed ideas through space and time. Whilst partially accurate, a broader social model emphasises that documents not only "deliver meaning", but through their circulation, define and maintain communities. The focus shifts to the ways documents serve as a medium for negotiation within communities, and the role they play in structuring discourse. These negotiations may range from annotations and conversations to formal meetings, sometimes mediated by collaborative and broadcast media.

Paper-based scholarly publishing continues to reinforce the model of 'documents as darts', since paper does not easily support negotiation over large distances. The typical journal review process severs many of the links between a submission and the discourse it provokes, and between the end product and the process that shapes it. This has shortcomings in that questions go unanswered, confusions go unclarified, criticisms go undefended. Reviewers (and readers) engage in an imaginary debate with distant authors who are not present to respond. The dynamic cut-and-thrust of debate is not well supported.

An appropriate tempo of debate for peer review should balance such dynamic exchanges with more reflective writing, leading to thoughtful, asynchronous discussions. However, whilst this has been possible in principle for many years over the Internet, the Web provides the best opportunity yet to reflect creatively on how scholarly publishing and discourse can be *integrated* to transcend some of paper's expressive limitations. Kolb [18] differentiates "scholarly hypertexts" from other kinds, focusing on the particular demands of scholarly inquiry that need to be supported: "questions, assertions, argumentation, evidence, and a community of inquiry to which writing is submitted for judgement" (p.30). Such a definition is relevant to both science and technology, and the arts and humanities, although their evident differences could lead to interesting variations in supporting technologies.

We are developing socially based models of scholarly publishing to design and test hypertexts with particular attention to the processes of *interpretation* and *negotiation* in different communities. How do we initiate exploration of the new forms of discourse that hypertext could mediate, in a way that helps communities evolve their current practices? Our strategy has been to start with the conventional document and familiar modes of discourse (e.g. journal peer review) in which researchers are highly literate. We then evolve these by introducing tools and methods which promote practices central to scholarly inquiry but that are poorly supported by paper.

The first part of the paper focuses on support for author-reader negotiation. We identify four principles derived from hypertext argumentation and design research which set the context for the design of the Digital Document Discourse Environment (D3E), a publishing toolkit that generates a Web user interface for reading, critiquing and debating documents. This has been used to publish an electronic journal. The second part of the paper focuses on the interpretation of ideas in relation to other work. We

describe a representational scheme for expressing conceptual relationships between documents that could assist researchers in locating and analysing them.

FOUR HYPERTEXT DESIGN PRINCIPLES

Argumentation has proved to be something of a "laboratory rat" for hypertext research. Systems that pioneered features such as graphical browsers and schemas of typed nodes and links have used argumentation as a proof of concept, e.g. [7,21-23,26]. Over a period of six years, we have surveyed, prototyped and evaluated the usability and effectiveness of various argumentation systems, particularly in the context of design rationale capture [5,28]. Such systems are designed to support the representation and analysis of arguments, and to capture the decisions and reasoning behind design artifacts. Drawing on this research we have formulated four principles that have guided our approach. Some of these principles are realised through system design, others through social means:

A: Avoid elaborate discussion structuring schemes.
B: Integrate document media with discourse.
C: Redesign work practices to emphasise discourse.
D: Support the new practices with tools.

Principle A: Avoid elaborate schemes for structuring discussions. If users classify their contributions to an on-line discussion, greater computer support can be provided. For instance, one can search for all *Theory* comments that have *Contradictory Evidence*, if those categories have been defined. A number of expressive linking schemes have been proposed (e.g. [7,8,30]). These, however, run the risk of burdening people with excessive overhead by requiring them to understand the system's scheme, and then choose how to categorise their contributions within these constraints. Studies show that users are often unwilling and/or unable to use elaborate schemes particularly in fast moving conversations (face-to-face or online) or when ideas are still vague, because the effort is too great [6,25]. The degree of explicit structuring that users find acceptable is a function of how well structured the ideas are that they want to share, their experience with the scheme, the time available to decide how to encode ideas, and the perceived benefits of contributing more highly structured information. We have, therefore, been careful to design a very 'low structure' discussion environment for researchers who wish to comment on documents or engage in discussion with other commentators, particularly as such users may be new to Web-mediated discussions. This informal 'layer' of discourse on the document complements the more structured document encoding layer that we describe later.

Principle B: Computational tools must tightly integrate documents with their associated discourse. Many systems place documents in a different application to discussion about them (we see this with e-mail discussion lists for Web e-journals). This separation hinders users from quickly accessing relevant comments when they are most needed and makes it hard to add contextualised comments. Likewise, tools should tightly integrate the textual parts of documents with any computational parts. Research in design support tools has shown that users need to easily bridge the separation between different representations of the design, and between representations and design rationale [11]. In our case, we must enable users to move seamlessly between reading the document and making a comment, and between reading and interacting with an embedded demonstration.

Principle C: Work practices must be redesigned so that structured discussions are an integral product of the overall task. Studies show that people often do not contribute to discussions because it is perceived as extra work over and above what they are already required to do [15]. Successful approaches have redesigned work practices to make contributing to a discussion integral to the overall task being performed [29]. Others also advocate 'seeding' (providing some initial contents), arguing that people find it easier to contribute to a discussion site with content designed to promote debate, rather than starting from scratch [12]. In a journal review context, this means redesigning the review process to require electronic threading of reviews into a shared space, and changing the traditional roles of editor and reviewer. Thus, redesigning practices is not simply about instituting new processes, it changes the roles and division of labour between community members.

Principle D: Tools are needed to support the new work practices. Many people may lack the technical skills, time, or inclination to engage in hand-crafting new digital document forms. Support is needed for automating the tedious and error-prone parts of the document creation process and to make it accessible to non-technical participants. Tools should be designed to make a good first approximation and then allow for humans to refine and correct the tools' output. The challenge is to create tools that are supportive, yet do not hinder the formation of new practices. This is the role of the D3E Publisher's Toolkit.

THE D3E TOOLKIT AND HYPERTEXT ENVIRONMENT

The D3E Publisher's Toolkit generates a Web-based environment to support structured negotiation about scholarly documents. We have been using D3E to support the publication of the Journal of Interactive Media in Education (JIME) [17], and several other scholarly hypertext sites [16,27]). JIME enables readers to directly experience interactive demonstrations of the systems being described by authors, through embedded or downloadable interactive demonstrations (*Principle B*). JIME has also been designed explicitly to support the processes of argumentation and negotiation which lie at the heart of scholarly peer review. We have detailed elsewhere [27] how the traditional roles and division of labour in the journal review process are being co-evolved with the tools (*Principle C*).

The simplest way to describe D3E is to step through a common scenario in JIME's publication. The editor imports a submitted HTML document into D3E on her computer. She selects (or creates) the type of Publication (which determines content and user interface features in the generated site), and then fills in information on the Article (Figure 1). The toolkit can then generate the document reading and discussion environment shown in Figure 2. The discussion environment is currently generated as a HyperNews [19] discussion, but we are exploring the interfacing of other Web-based discussion environments to D3E. An extract of peer review argumentation between JIME authors, reviewers and editor is shown in Figure 3.

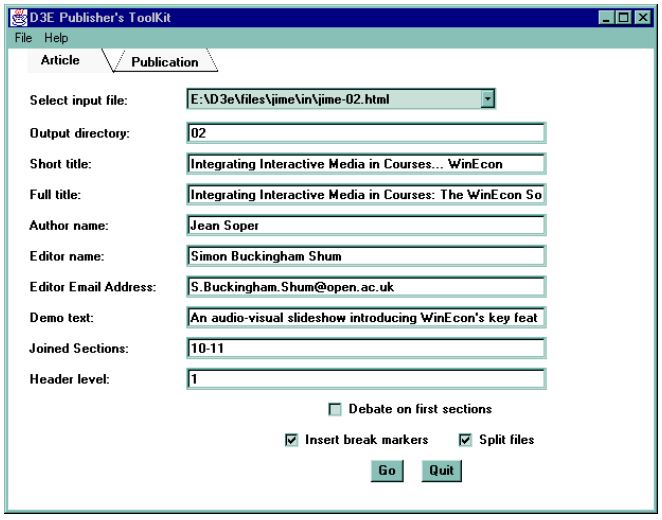

Figure 1: In the D3E Publisher's Toolkit, the editor fills in the details of the paper to be published on the Web.

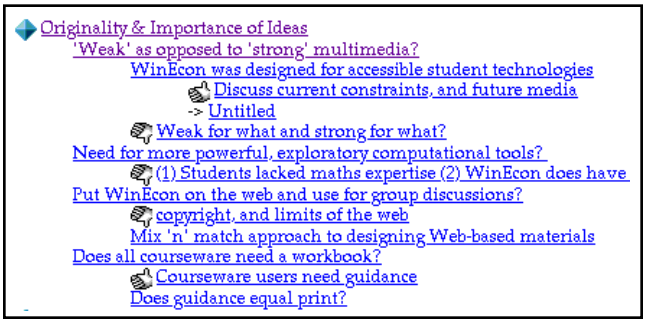

Figure 3: Outline of one thread in a review debate. 'Originality and Importance of Ideas' is a standard discussion category. Five of the contributions shown are from reviewers, five are from the author, one is from the editor, and two are from readers. Authors have the option of tagging their contributions as Agree/Disagree, reflected by the thumbs up/down icons. This is the only additional coding offered at present, so maintains simplicity.

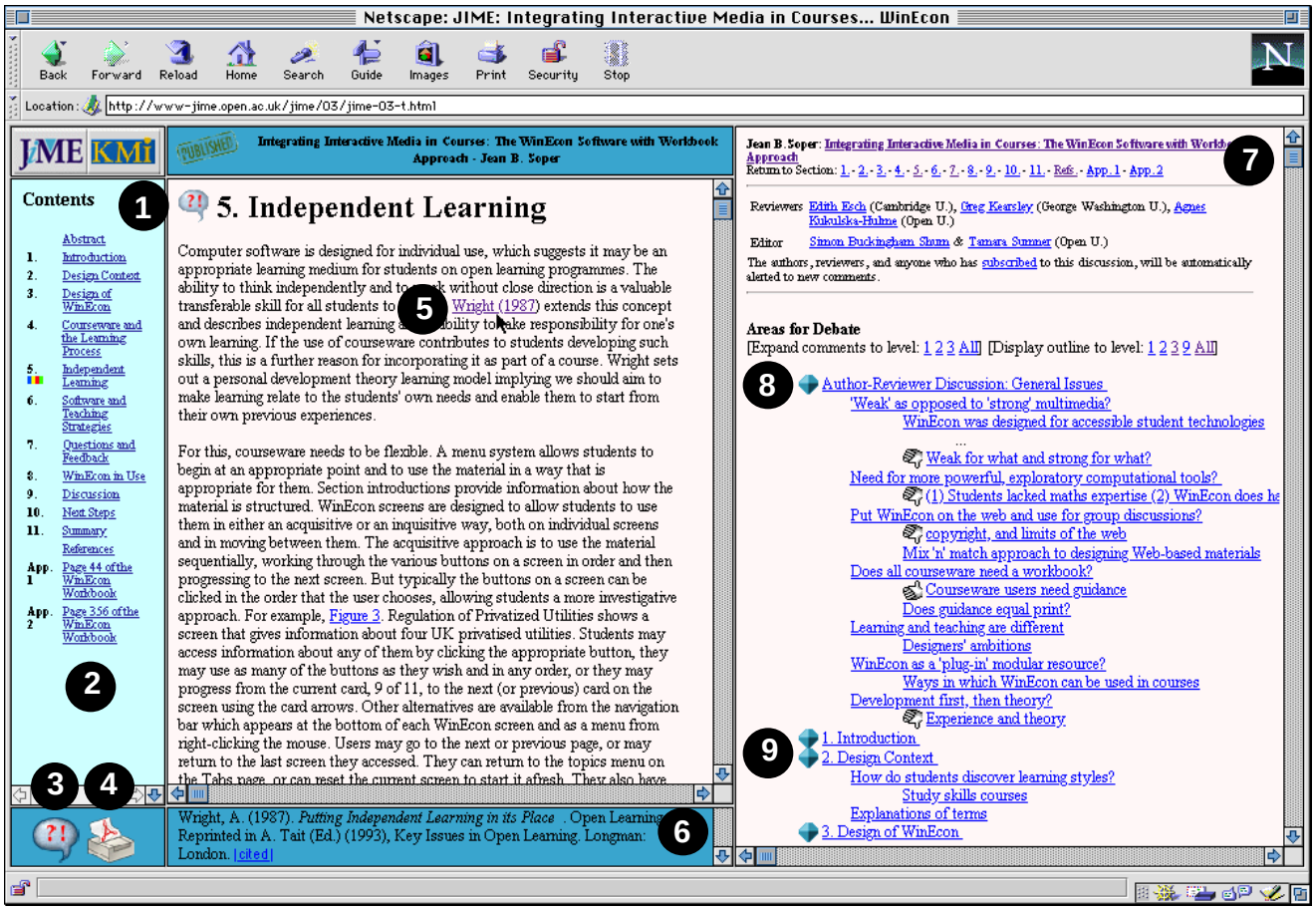

Figure 2: Output of the D3E toolkit from a source HTML article. On the left is the Article Window, on the right the Commentaries Window showing the top level outline view of discussion about the document.

Key: [1] Comment icon embedded in each section heading: displays section-specific comments; [2] active contents list; [3] iconic link to display top level discussion outline, as shown on right; [4] iconic link to download Acrobat version; [5] citation is automatically linked to entry in references, displayed in footnote window; [6] reverse link to citation(s) in the text; [7] links from discussion back into article; [8] general heading (defined in toolkit) for discussion on the whole document; [9] headings for section-specific comments.

To summarise thus far, D3E and publications like JIME reflect a more process-oriented view in which we recognise and support discourse surrounding documents. We describe our experiences further in [27]. As it stands, D3E facilitates *negotiation* about *individual* documents. We now explore ways in which D3E could be developed to generate more sophisticated environments for *interpreting* documents in the inter-textual context of the literature in which they are embedded. The focus shifts from the relationship between a single document and its discourse, to *inter*-document relationships and discourse promoting contrasting perspectives within and between intellectual communities.

REPRESENTATIONS TO SUPPORT INTERPRETATION

Framework: perspective making and taking

Boland and Tenkasi [3] highlight the importance of what they term *perspective making* and *perspective taking* in communities. "Perspective making is the process whereby a community of knowing develops and strengthens its own knowledge and practices" (p. 356). It is this process that underpins the building of a community's identity: their basic assumptions, goals, terminology, stereotypes and modes of discourse. "Perspective taking" refers to the process of trying to engage with another community's perspective. This can be a difficult process when their respective "ways of knowing" offer radically different, and strongly held, foundations for reasoning.

Process	Hypertextual 'structural signatures'
"Perspective making"	
"complexification" (evolution and refinement of definitions)	specialisation and abstraction transformations on structures, or specific node/link types
increasing knowledge domain	increase in domain and problem-related entities
refinement of "language games" and "narrative forms" (conventions in the use and structure of language)	emerging regularities in the construction of structures for expressing and contesting ideas
"Perspective taking"	
recognising existence of other perspectives	multiple structures for representing the same information
surfacing of differences through representations that serve to focus discussion	tools to visualise and compare different conceptual structures
recognising blindspots in one's own perspective	tools to discover which concepts have been addressed in different views of a network
critical discussion of different perspectives	self-representation within hypertexts, to enable existing structures to be reconstructed and critiqued

Table 1: Mapping between processes of perspective making and taking [3], and structural signatures.

Clearly, perspective making and taking are central to research. Could hypertext tools assist these processes? Table 1 shows a possible mapping between features that Boland and Tenkasi identify, and 'structural signatures' that hypertext tools could manipulate. We illustrate through a number of examples below how perspective making and taking could be supported and analysed given an appropriate infrastructure on the Web.

Representational requirements

What kind of representational scheme could support the making and taking of perspectives within scholarly communities? Let us begin with a future scenario from JIME:

> Jo is a physics lecturer seeking principles for using educational multimedia. She has found a JIME article [A] describing an interesting atomic physics simulation system. On request, JIME's search engine displays a map of other publications in JIME that have potentially relevant theoretical perspectives. She selects an article [B] and finds that it describes a conceptual framework for deploying multimedia in a branch of medical education. Jo asks to see the relationship of B to A, and finds that the problem types underpinning article B's framework are very similar to those addressed by the physics simulation system.

This sort of enquiry could be supported if documents and their inter-relationships were more richly encoded in computer-interpretable form. If the encoding scheme was well designed, the resulting network could allow researchers to search for or be automatically alerted to publications such as:

- a new theoretical perspective *T* on problem *P*;
- new contradictory evidence *E* pertaining to the effectiveness of a class of solutions *S* to problem *P*;
- a new language *L*, derived from *L1 and L2*, for addressing problem *P*;
- a new analysis *A* derived from theoretical perspectives *T1* and *T2* derived from *T*.

One could also query such a network in order to:

- display the structure of part of a theoretical debate, e.g. all empirical evidence to support an analysis;
- display all systems of class *S* which use a particular language *L* in addressing problem *P*.

What is required therefore is a representational scheme for encoding documents, and an infrastructure that links them. The rest of this paper describes such a scheme, and several examples to illustrate its potential. The technical implementation is at this stage not of primary concern, although we discuss it briefly. Our focus is on designing a scheme for describing documents that scholars will find both *usable and useful* for "perspective making and taking." These dual requirements require a design solution that balances simplicity with expressive power.

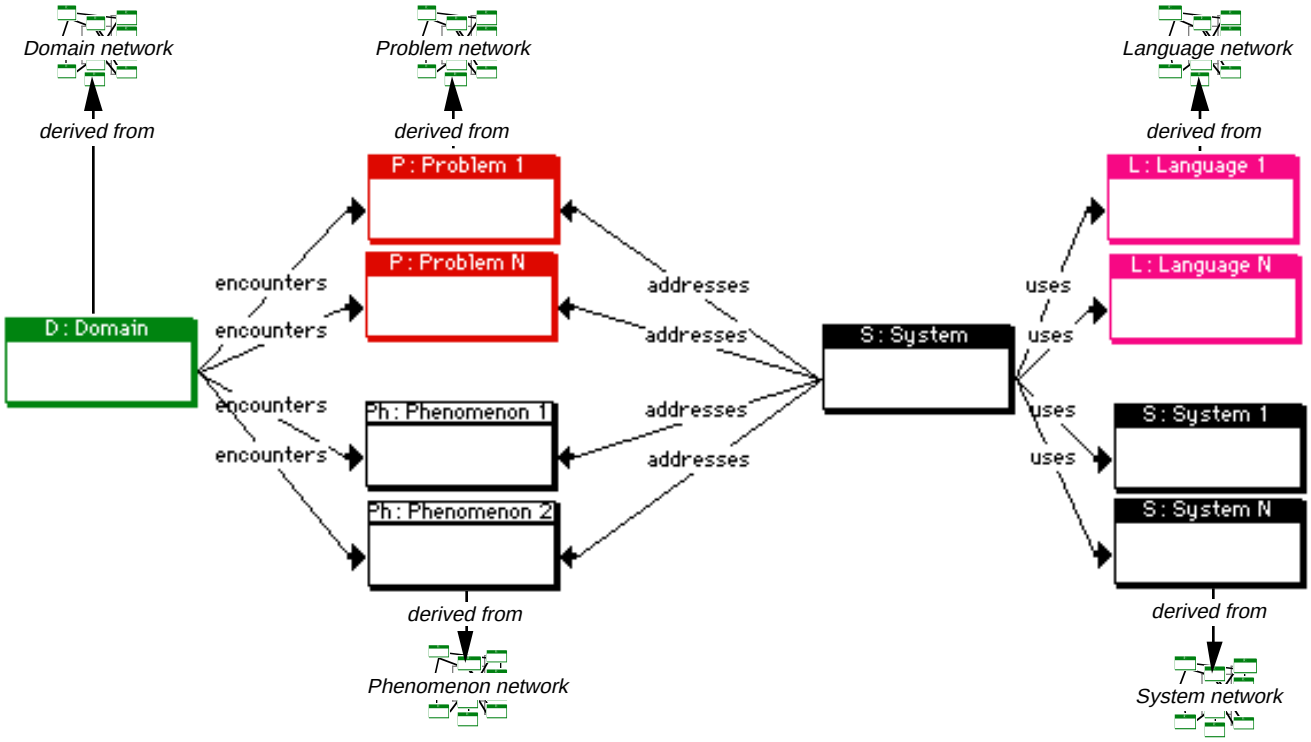

Figure 4: An encoding scheme that could be used to describe a new system. Any node can be a composite, that is, an encapsulation of its constituent concept network (see Figure 6). Note that the spatial layout of this figure (and others) is designed primarily to express the semantics of the encoding scheme, although it indicates the kind of visualisations that users might work with.

A representational scheme

We plan to extend D3E to support the publication of JIME articles with a semiformal layer of description, capable of supporting scenarios such as the above. Let us begin with the claims and forms of reasoning that typically underpin the description of a new software system. This proposal is grounded in an analysis of submissions to JIME, and of typical research papers in hypertext and human-computer interaction. Firstly, in a given *Domain*, we encounter one or more *Problems*. *Systems* may be proposed to address these, and these in turn use one or more *Languages* (in which they are implemented, or by which the domain is modelled). A System is often built on one or more existing Systems. If the Domains, Problems and Languages of concern may have been already published by others they can be simply referenced; if not, new descriptions are added to the pool of published material. This pool takes the form of a shared, extensible network (see next section). This set of relationships is summarised in Figure 4.

Of course, not all research contributions are descriptions of new software systems. Figure 5 shows a set of relationships that enables an author to express various kinds of *Analysis*. For instance, an Analysis might *identify* a new Problem or Phenomenon, or *characterise* an existing Problem in order to *motivate* a new Language. A Theoretical concept may be *derived* from another in certain ways, *predict* a Phenomenon, or *challenge* another Theory.

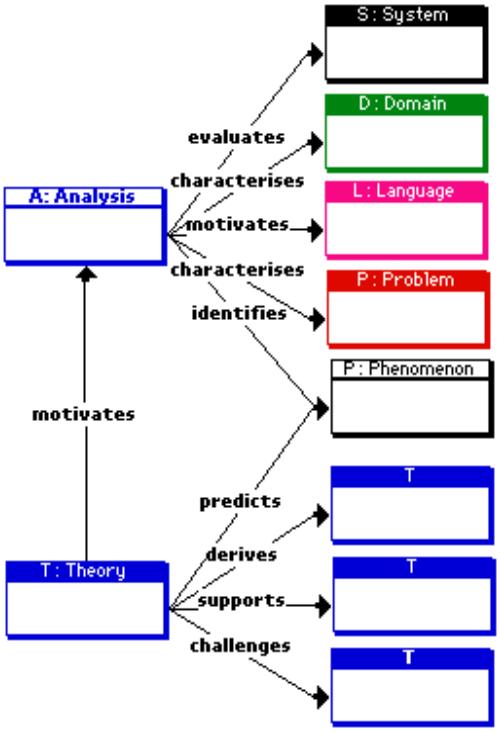

Figure 5: Expressing different kinds of analyses and theoretical relationships. All of the relationships from *Analysis* are applicable to all other node types, but for clarity are not shown.

Compared to a conventional keyword classification scheme, adding semantic structure provides a more expressive framework for describing a new document, and implemented as a searchable network, could be searched and visualised as outlined in the JIME 'future scenario'. We plan to extend D3E to provide a user interface for constructing descriptions, from which the tool will generate encodings.

Integrational infrastructure

Integration is required for a search engine or agents to follow links between articles. As the journal's editors, we plan to develop skeletal classification schemes of domain-relevant entities (Problems, Domains, Languages, Systems, etc.). These will provide the common reference and starting point for encoding articles. These will take the form of networks which grow through the addition of multiple, partial, evolving hierarchies:

- *Multiple*, since there is no single view of the world—different hierarchies reflect different perspectives. A shallow hierarchy with cross-links analogous to the ACM Computing Classification Scheme [1] is one possible scheme to use as a seed for the networks.
- *Partial*, since authors will be defining entities as instances of others to serve their particular perspectives. The structure of the Problem/Language/System design space outside this scope will be left to other researchers;
- *Evolving*, as new publications are encoded, the network is extended and refined.

Conceptual and implementational progress in browsing and editing ontologies via the Web [10,13] demonstrate one route to the collaborative evolution of knowledge structures such as these. We are also tracking developments in architectures for metadata schemes [31] as a complementary route.

In summary, our design goal is to maximise the power of the network whilst minimising the effort to encode a document. Gruber [14] has referred to "negative knowledge acquisition cost" as a computational system's ability to analyse information without users having to structure it explicitly. Our proposed encoding scheme could make much finer grained distinctions in node-link types, but we wish to see how much expressive power the network can provide from material structured at the proposed granularity, in order to relieve individual encoding effort. We now present several examples of the encoding scheme to illustrate how we envisage it being used, and the expressive power that it affords.

Example 1: encoding this article

Let us begin by using the scheme to describe our own work as represented in this article. The case we make for this is encapsulated as follows: in the Domain of *scholarly publishing*, an Analysis of *scholarly hypertext between documents* identifies the Problem of *tracking research*. This motivates a new Language, the *encoding scheme*. Figure 6 illustrates how we could express this case.

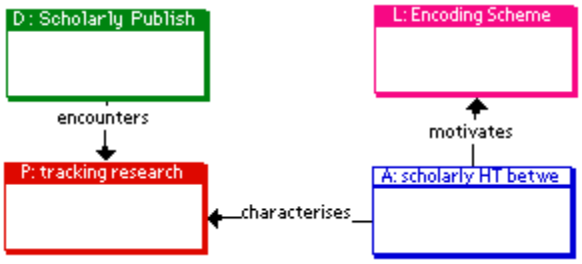

Figure 6: Part of this article can be encapsulated as an Analysis that characterises the Problem of *tracking research* in the Domain of *scholarly publishing*, which motivates the proposal of a new Language, the *encoding scheme*.

If we consider the process of creating such an description, we can envisage that *scholarly publishing* would already exist in the Domain network, and we would select it via D3E or a Web client that could access this. We could define the Problem of *tracking research* as *an example of* a more general class of Problem such as *tracking information*. The *encoding scheme* is obviously a new construct, which would need to be linked into the Languages network, perhaps as an example of *metadata schemes* in general, or for example, as an extension to a specific scheme such as Dublin Core [9] or W3C's RDF architecture [31]. The Analysis node is primarily there as a target object for other researchers to link to; it represents our case for an encoding scheme. In Example 3, we consider what might lie "inside" an Analysis node. It would certainly point to those parts of the source document that make the case for the encoding scheme, or if these are not clearly defined, to the document as a whole. However, it might also point to finer grained encoding structures, setting out an important part of our argumentation using constructs as shown in Figure 5, or highlighting important relationships in other work.

A second contribution of this article is the D3E system. We could express this as follows (Figure 7): the Domain of concern is *scholarly publishing*. Two Problems encountered are that *documents and debate are separated*, and the *poor review process*. In this context, an important Phenomenon is that of *informal web publishing* by scholars. The *D3E* System is proposed as relevant to these. It uses *Java*, and is built on the existing *HyperNews* System (which itself uses other systems—see details under Figure 7). Figures 6 and 7 could then be linked through another Analysis node expressing our proposal that the *encoding scheme* be embedded in *D3E*, thus becoming another relevant Language.

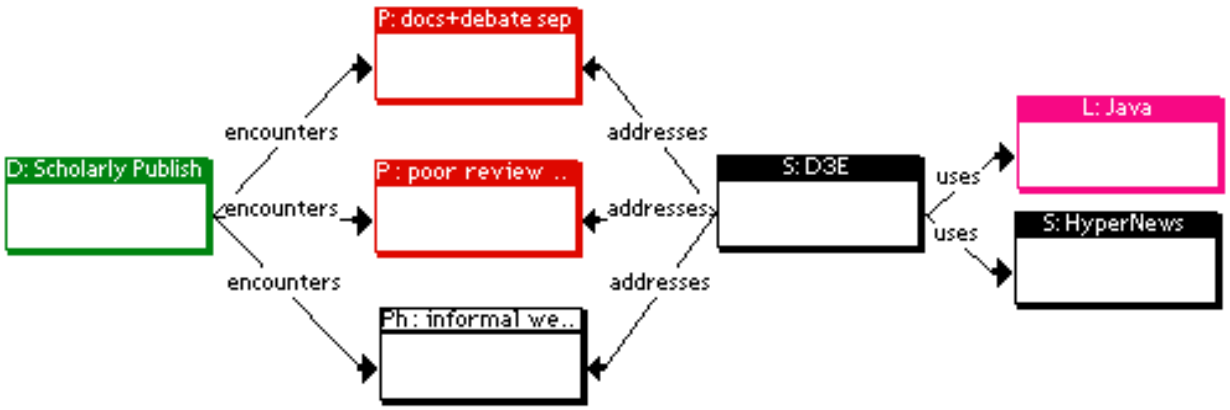

Figure 7: Using the encoding scheme to describe the D3E System, as presented in this article. All nodes are linked into their respective shared networks (see Fig. 4). If we assume that the systems on which *D3E* depends are already described somewhere, only D3E's immediate properties need to be made explicit. D3E inherits the properties of other systems: thus, *HyperNews* uses *PERL,* and is built on the *WWW* which uses *HTTP*, and so forth. *HyperNews* acts therefore as a composite node pointing either to more encoded information (pointing to a source document), or direct to an unencoded online document (e.g. the HyperNews site), or simply to a reference provided by us as the authors.

The benefit to other researchers is that wherever the *encoding scheme* is referred to, it is now possible to find out what motivated its development. Wherever the problem of *tracking research* is encountered (perhaps in Domains other than *scholarly publishing*), it is now possible to show relevant Analyses and solutions. Conversely, and to our benefit as authors, researchers in other domains will be alerted to D3E or to our encoding scheme because they are working on concepts related by one or more networks (e.g. Languages; Problems; Domains) to our article (see also Example 2). We could construct further 'fragments' of encoded structures to make explicit other conceptual or implementational details that we felt were particularly important to our approach, and which would assist in making contact with interested research groups.

Example 2: the JIME scenario

The 'JIME scenario' envisaged a researcher discovering a theoretical framework relevant to an article of interest. Figure 8 shows how this could be realised through encoded documents linked by a Problem network. The Problem network makes possible many kinds of "overlap" in Problems. Article A's problems may have been defined as *derived from* those in Article B, or *dependent on*, or *instances of*.

Example 3: Making and taking perspectives

We proposed earlier that perspective making/taking might be facilitated if a hypertext environment could detect

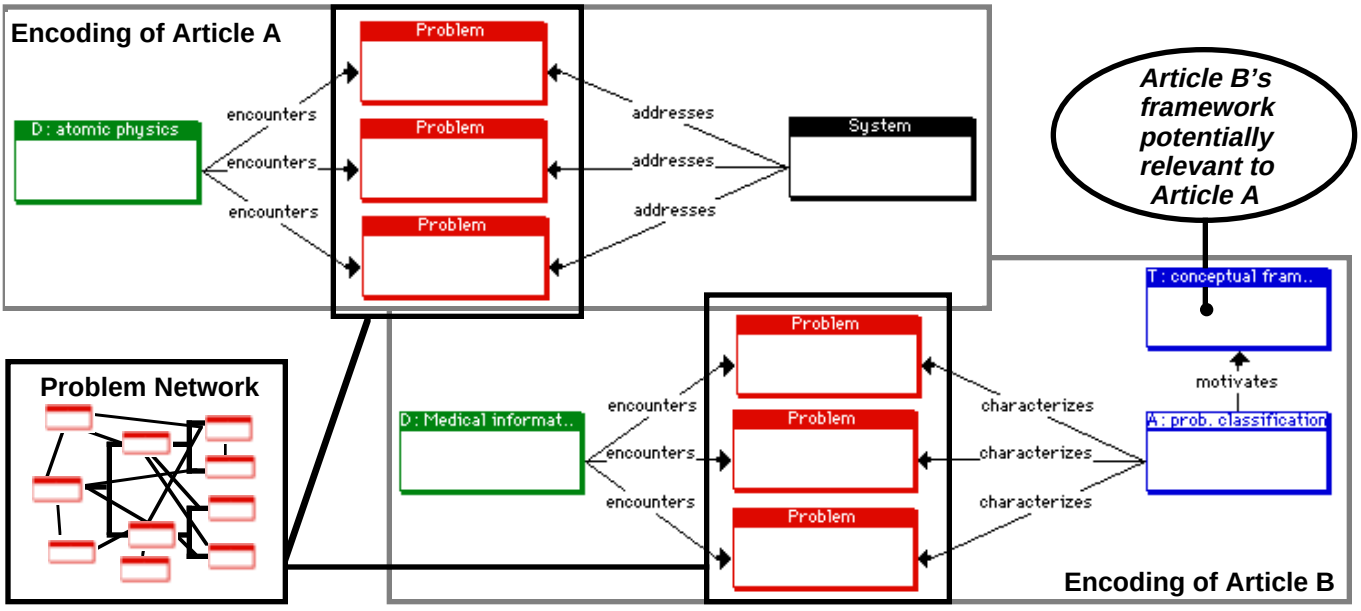

Figure 8: Representations underlying the JIME scenario. A Problem network is maintained by the journal, and used to encode publications. A request to see theoretical work relevant to Article A can therefore display the framework in Article B due to overlap in the Problems that they address.

'structural signatures'—emergent patterns in a large, shared repository of encoded documents that reflect the formation of coherent viewpoints. Drawing on our encoding scheme, we explore this possibility further in our final two examples.

By definition, one would expect adherents to a coherent perspective to criticise work derived from common theoretical perspectives, and to support work derived from others. Within the shared ontology that we seed for JIME will be a network of theoretical concepts. Clusters of related work will form as authors populate this with new concepts and declare relationships such as *supports*, *challenges* and *derives*. If two documents challenge concepts in one cluster, and appeal to concepts in another, we might hypothesise that they share a common perspective. Figure 9 shows this schematically.

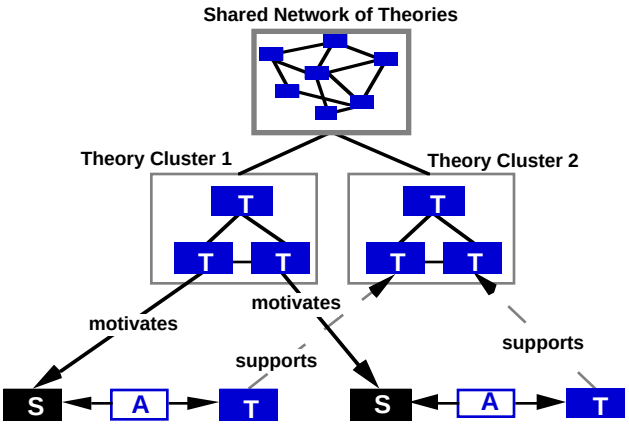

Figure 9: Two *Analyses [A]* are made of two *Systems [S]*, resulting in two Theoretical *concepts [T]*. In both cases, the Systems are motivated by Theories in one cluster, and the two Analyses motivate Theories which support a different cluster. This could signify a common perspective between the two Analyses.

Another example of structural signatures is to signify consistent differences in the way that perspectives interpret the same concepts. One perspective may take them for granted, or explicitly declare them to be supporting evidence for their case, whilst another problematises these concepts. This is illustrated by the example in Figure 10.

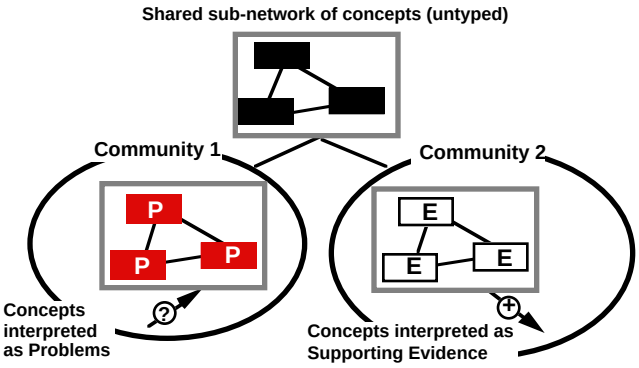

Figure 10: A set of entities is interpreted by Community 1 to be *Problems* that need to be addressed, whilst Community 2 interprets them as *Evidence* that supports their case. Such differences could signify contrasting perspectives, and visualising could assist perspective taking and negotiation.

Leigh Star [20] has documented the importance of 'boundary objects'—artifacts that provoke reflection across community boundaries, and Boland and Tenkasi discuss their role as representations symbolising a perspective which can facilitate perspective taking. We propose that structural signatures based on our encoding scheme could play precisely this role.

DISCUSSION

Balancing multiple levels of formality

We have proposed the addition of a third layer—semiformal encodings—to the documents and threaded discussion in JIME's D3E-based infrastructure. As we have emphasised, studies of our own [6] and others [24] leave us acutely aware of the cognitive overheads of structuring information semiformally. How does our approach recognise these findings? Firstly, the semiformal layer is not the only level at which inter-document discourse can take place. This layer will be as tightly integrated with the others as document and discourse are already, so informal annotation of semiformal structures via the commentary layer is an alternative route to semiformal annotation. We wish to maintain multiple levels of formality.

Secondly, if authors have a subtle and complex argument that they are unable or unwilling to structure semiformally, they can 'minimally link' their whole document to an Analysis node, and link this node to at least one general node in one of the shared networks (e.g. declare a relevant Domain). This leaves the crafting of the text to do the expressive work, and no further 'dissection' of the conceptual structure is necessary. It is then sufficiently encoded for others to locate. Another researcher may choose to 'explode' part of this Analysis node by making explicit particular relationships that they interpret the author to be asserting. The validity of this *re*presentation can then be contested.

Consistency and synonyms

In our examples, an obvious problem is ensuring that researchers express the same concept in the same way; it may arise several times in different places through synonymous naming. As ever, the solution is a combination of both human and computational checking. When declaring that I am addressing the Problem of *tracking research developments*, it is my responsibility as an author to check the Problems currently registered (at least in the domain of *scholarly publishing*) to ensure that it does not already exist under some other name (the system could also check for name clashes). If for any reason two very similar concepts do get registered, then one might reasonably expect that over time, very similar structures will grow up around them, as different researchers make links from them to the same Theories, Analyses, and so forth. This is the kind of useful structural signature that could signify related areas of work. An emergent property of the proposed network would, therefore, be convergence between overlapping work so that authors would be alerted and could negotiate how their different views inter-related. Obviously, such processes are already an important and exstablished part of doing research.

Would hypertext increase inertia to change?

Would making explicit the structure of research debate increase the inertia of a field of enquiry to change, or in fact facilitate fundamental challenges, even paradigm shifts? If elaborate structures have been developed in line with one theoretical or paradigmatic perspective, will this not increase resistance to arguments to change this?

We argue to the contrary. Firstly, explicit, sharable representations facilitate reflection. A good representation focuses analysis on important features of the domain. It also serves as a focus for debate itself—is this a sufficiently expressive scheme? What assumptions does it make? Does it bias towards one perspective or another? Secondly, one of the primary goals of hypertextualising information is to make it possible to reach an information element via different routes, and thus, to set it in different contexts. Encoding elements of scholarly debate using a hypertext scheme of the sort proposed should foster exploration of multiple interpretations of a concept. Used well, hypertext provides powerful tools for re-interpretation and re-contextualisation.

Generalisation and scalability of the approach

The scenario we have explored so far sets out our plans for improving the service offered by a specific e-journal, which we shall use to evolve the representations and support tools. The natural extension of the approach would be a distributed network sustained by a research community whose members encode their research documents via a network of servers (institutions' digital libraries being an obvious candidate). Researchers would search one or more networks as outlined in the scenario, and would be alerted to the presence of potentially relevant new work matching their profile of interests. One such initiative has already been launched in the knowledge modelling community [2], and D3E will be used to support negotiation about this community's ontology as it evolves.

We are aware that the encoding scheme presented has a bias to science and technology research. If the scenario of *community*-wide publishing and debate unfolded, we would expect other disciplines to evolve their own schemes in line with their requirements. However, the key to preventing interdisciplinary fragmentation is to develop linkage through one or more of the shared networks that we have proposed. Thus, a biologist and a software designer should be able to find each other if they are both applying the general theory of autopoieses. The nature of such cross-disciplinary linkages already constitutes the work of researchers in autopoieses. In a hypertext enriched as we propose, much of their work would inform the construction of interdisciplinary Problem and Theory networks that would then be available to all researchers.

In conclusion, we have described the evolution of our approach to scholarly hypertext publishing, exemplified by the D3E Web publishing toolkit and the e-journal JIME. We have also presented theoretical and representational principles for declaring inter-document relationships that could support conceptual analyses. Immediate plans are to evaluate the usability of the encoding scheme with authors, and extend D3E to assist the encoding of documents. Medium term plans are to implement a scalable Web infrastructure, beginning with our journal, and investigate visualisation techniques that could support scholarly inquiry of the sort that we have described.

ACKNOWLEDGEMENTS

The D3E toolkit and environment are implemented by Malcolm Story and Mike Wright. We are grateful to Chaomei Chen, Cliff McKnight, John Domingue, Steve Hitchcock, David Kolb, Enrico Motta, Gerry Stahl, Arthur Stutt and Zdenek Zdrahal for feedback on earlier drafts.

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