Ontologies and Technologies: Knowledge Representation or Misrepresentation

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The development of the Semantic Web (SW) raises a number of difficult and interesting technical issues. Less often remarked, however, are the social and political debates that it will engender, if and when the technologies become widely accepted. As the SW is a technology for transferring information and knowledge efficiently and effectively, then many of these questions have an epistemological base. In this paper I want to focus especially on the epistemological underpinnings of these social issues, to think about the interaction between the epistemological and the political. How does technology affect the social networks in which it is embedded? How can technology be successfully transplanted into a new context? And, perhaps most importantly for us, how is technology affected by its context? In particular, I want to look at how our decisions about how we treat knowledge can impact quite dramatically on the technologies we produce.

Let us begin with a familiar diagram, the layered view of the SW developed in the very early stages by Tim Berners-Lee and colleagues (Figure 1). Knowledge of different types is separated out (ontologies appearning in the middle). And by making this separation, we can see how the semanticity of the Semantic Web comes about. The technical machinery of Unicode and URIs appears at the bottom; XML can be used to tell the computer what objects this code is concerned with. RDF tells us that those objects are related in various ways. Ontologies give a context for the object types and relation types. We then need logic and inference engines to make context-sensitive inferences over our knowledge bases. Proof theory tells us the properties of our inference engines – soundness and completeness etc. And finally, there's no point being proven innocent if no one trusts the method of proof.

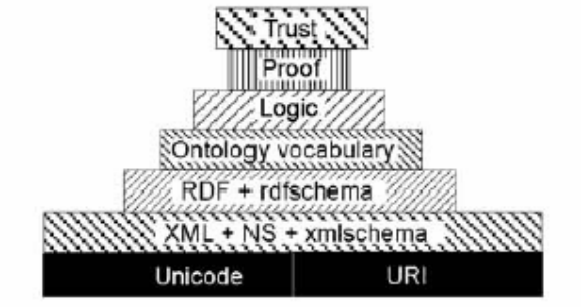

Figure 1: The layered view of the SW

Hence, ontologies are central to the vision of information aggregation and manipulation underlying the Semantic Web. Ontology-mediation within services enables much to happen; they can steer the knowledge acquisition process, choreograph the integration of information from diverse sources and representational formats, assemble retrieved information into customised packages, and hence present information to the right people in the right form, bring intelligence to the search process, undercutting the direct human input to the drudge work.

An example of an ontology-mediated system which exploits the new expressivity that the SW allows is the winner of the 2003 Semantic Web Challenge, CS AKTive Space (Shadbolt et al 2004), which gives an up-to-date snapshot of the state of the discipline of computer science in Britain. But the point of view of the snapshot is determined by the user. In a massive knowledge acquisition exercise, various different technologies assemble giant quantities of research-related information from the websites of computer science departments, the EPSRC and so on. This is all collected on a regular basis, and converted into RDF. The RDF store contains tens of millions of triples, and the space enables the user to query that store to ask specific questions about British computer science. Who is working on what? Who is working with whom? Where are the geographical concentrations of researchers? Which areas are receiving the funding? Who are the top people in different areas?

Ontology mediation is central to this flexibility in the presentation and selection of information; how does this impinge on the social aspects of the SW?

There are two ways in which the Semantic Web can be seen as social. The first is that, as we ascend Figure 1, the layers become increasingly socially rooted. In other words, even though all of these layers are amenable to technical solutions (even trust, a social phenomenon *par excellence*, can be addressed technically, as we see, of course, in the agents community, and increasingly in Semantic Web services), as we move up, each layer is more beholden to social phenomena. No matter how good the technical solutions provided, as we move along the direction of the arrow, those solutions must respect more, and more complex, social phenomena. They can be criticised by pointing out that, no matter how impressive the solution, it fails to capture some vital aspect of reality.

The other social aspect of the SW is common to all technologies: it exists in a context, and is intended to move in other contexts. It will be crucially affected by developments and demands from the economic world, information security and assurance, defence and government, organisational and managerial innovations, the entertainment industry, and, not least, academe. We have already seen this social influencing with the World Wide Web. The Web was an interesting space for action, and developed accordingly, but when people wanted to use their credit cards online, suddenly a new set of research imperatives was created, to do with security and identity verification. We must expect analogous events in the future of the SW.

We must also not forget that these influences are two-way. Technologies are transformative, and the Semantic Web may well affect the structures and practices in all these areas.

If we take these social aspects of knowledge seriously, then we need to move away from traditional epistemology (O'Hara 2002). In this view, knowledge is a kind of Platonic entity. We can "tap into it" when we have some kind of knowledge system, be it organisational information processing, or machine readable repository, or just in

our ordinary educational learning. In other words, knowledge is *abstract*, and then is *concretely* represented more or less well. On this view, we might see the ideal knowledge transfer process as like a frictionless plane, where no content is lost through the transfer process, and the Internet as some superconducting medium which can approximate that.

We need to switch to a more materialist view, where what we expect is a series of more or less costly translations from form to form, representative mode to representative mode (O'Hara 2002). Each translation from form to form may well lose content, or involve generating new knowledge. Rightness or wrongness of translation is a factor, but so is correctness for the task. In other words, knowledge manipulation is conceived of as a *material* process, using *resources*. Friction cannot be avoided, even on the Internet (Fuller 2002).

What we are talking about is the codification of knowledge. Knowledge has certain properties; there are things it can do in the world, depending on how it is represented, and what institutional forms lie behind it. Codifying it in a certain way will affect those properties. For example, one radical type of codification is what the knowledge management theorists Nonaka and Takeuchi call *externalisation* (Nonaka & Takeuchi 1995). This takes tacit knowledge, know-how or knowledge that people possess but has not been written down, and explicitly creates a codified, or explicit, version of the know-how. We can study the effects of codification using externalisation as a common type of example.

There are many advantages of codification, of tailoring knowledge to one's organisational needs: it is easier to move knowledge around the organisation; sharing and retrieving it is much simpler; you don't need a person who actually has this knowledge tacitly in their head to be present. And when the owner leaves the organisation, the knowledge stays behind, in the manuals, the computer, the Intranet, or wherever the explicit codification is held.

Furthermore, the codified knowledge has become an *asset*; it is now saleable. It can act as the basis for a patent or copyright. The organisation can be granted monopoly rights for a period over the knowledge, and if others want to use it they will need to purchase a licence.

And finally, codification converts knowledge from what economists call a rival good to a non-rival good, i.e. it is now such that many people can use it at the same time. When the knowledge was tacit, then the owner had to be present when the knowledge was used. If he or she was needed at two places at once, they would have to prioritise, because tacit knowledge is a rival good. But once the knowledge is on the Intranet, for example, different people can download it at the same time (Cowan et al 1999).

However, once we consider the social, economic and organisational consequences of codification, some disadvantages also appear. In the first place, codification is expensive, it takes time, knowledge engineering, and so on. An expert is tied up during knowledge acquisition.

Furthermore, whereas tacit knowledge tends to evolve naturally, explicitly written down knowledge becomes ossified. It has to be maintained, kept up to date. That is all very expensive, especially when the domain is very dynamic.

Thirdly, where trade secrets or the competitive advantage of confidentiality are involved, a store of codified knowledge is much leakier. It can simply be emailed to a rival, unlike the years of experience in a person's head.

And finally, explicit knowledge is much harder to apply than fully internalised knowledge. Consulting a manual, or downloading material, is much more difficult. Tacit knowledge often includes much about its own application. With explicit knowledge, not only does the information have to be retrieved, but the user needs to know which information is important, and where it can be found (Cowan et al 1999).

So codification of any kind usually involves big and important tradeoffs.

- How is the knowledge to be secured? Do we want to go to law, get a patent? If we do, then the knowledge is public, it can be reverse engineered. If not, we have no comeback or protection? Do we need it?
- How is the knowledge likely to be lost to the organisation? Will it leave with its owner? Or is it more likely to be appropriated if we write it down?
- What is the knowledge worth to us? If it is tacit, then we will ultimately have to pay its owner more or less what it is worth to us. The labour market thus becomes a substitute for a knowledge market. How should we maximise our return on our knowledge acquisition or training expenditure?
- And not least, who benefits from codification? If we codify tacit knowledge, then we take much of its previous owner's economic power away from him. He used to be the monopoly supplier of that knowledge within the organisation. But when we codify his knowledge, it is readily available. What incentives could he possibly have for cooperating?

That brings us onto the economics of the situation. As we noted earlier, knowledge acquisition – codification – is expensive, but the expenses vary depending on a number of factors. Is there a code in place? Or will we have to create one? How adequate are the available codes? Will they prevent the codification going well?

Is there a consensus in the domain, or are there disputed views? Particularly in large corporations, different sectors, R&D, marketing, engineering, assembly, will conceptualise a domain very differently. If there is a dispute, then the operation of codification may involve taking sides. The chosen code may favour one side or the other. The person or team in charge of codification is at an enormous advantage in particular if it is party to the dispute. This is particularly important with respect to ontologies, which are supposedly *shared* conceptualisations of a domain. How are we to model disputes, when the actual content of the dispute may itself be disputed? Are there authorities to whom we can turn? Who accepts their authority?

And there are many different types of knowledge. For example, it can be taxonomic or hierarchical, encoded in diagrammatic form, distributed across an organisation, or it can be procedural knowledge. How can we deal with these different kinds of knowledge? Are some trickier than others? Are some types so hard to model that our models will always be too coarse and expensive (Brewster & O'Hara 2004)?

We can see some of these factors if we take an example from the early days of expert systems. Problem-solving methods (PSMs) were recurrent patterns in expert reasoning, that could be applied in different expert systems in different domains (Chandrasekaran 1983, Clancey 1985, Wielinga et al 1992). Such methods included hierarchical classification, systematic diagnosis, and propose and revise design. They could be used as skeletal expert systems, such that if they were filled in with domain knowledge, they could be used for problem-solving. Similarly, they could direct knowledge acquisition by telling the knowledge engineer what knowledge to acquire,

and signposting what type of knowledge is required for problem-solving (O'Hara et al 1998, van Heijst 1995). In other words, the PSM contains within it ontological specifications.

However, these specifications are highly task-specific. There is no guarantee that these ontological forms will be translatable for other tasks, or that the knowledge so painfully acquired could be easily reused for another task. When knowledge has a procedural element, there may well be difficulties in understanding how that knowledge could be reused, even partially, for other tasks. In general, the lesson is that certain types of knowledge (for example taxonomic knowledge) may well be easier to put into ontologies than others.

Given these thoughts about codification, how do they leave our questions about the Semantic Web and information retrieval? Are there questions raised by this which have yet to be properly addressed in the SW community?

Let's look at how we might expect the SW to be used. Corporations, organisations use knowledge technologies to help them make sense of a chaotic, uncertain world. They want the best support for their decision-making and problem-solving. They often operate in dynamic, disputed, contentious domains. They have only incomplete information, often in inconvenient form. What they want from their technologies is timely interpretations of the evidence to let them make reliable decisions, and to let them act effectively. Are ontologies the right things here?

They aren't very good at representing disputes and divergence, since they are shared and agreed conceptualisations of domains. They need to be available quickly as the domain changes, but they are usually painstakingly hand-crafted. There is little automation of development. They are hard to maintain. It is hard to remove out-of-date information, because it is hard to work out what depends on what within an ontology (Buckingham Shum 2004).

If we look at how organisations actually use ontologies, we find little consensus on what an ontology actually is. They tend to involve hierarchical taxonomies, but other than that, almost anything goes. What corporations tend to do with ontologies is to systematise large volumes of knowledge, for example to do with research and development programmes. The ontology therefore looks like a hierarchical corporate memory. Interestingly, knowledge is much more usually put in than retrieved.

Perhaps more interestingly, the big research issues as seen from industry are correspondingly different from those that excite the scientists. They include security and ownership, trust, how to communicate to different audiences, the intended audience in particular, and what media will be used for browsing and viewing. Hence the major challenge from the corporate user's point of view is not representational adequacy, but rather the social context of use. How should this system integrate with other systems, computational or otherwise? How should content be acquired or designed (Ellman 2004)?

So when we look at the use of ontologies in the SW from the viewpoint of its social context, we start to see a different set of problems emerging.

- *Which* knowledge should we be representing? And how? And what are the limits of our capabilities to do that? How disabling will those limits be?
- *Whose* knowledge are we taking? Are we disturbing patterns of ownership, redistributing power, legitimately?

- Should we try to represent *dispute*? How consensual should ontologies be?
- Can there be *personal* ontologies, and what use would they be?
- How do the *costs* of knowledge transfer get allocated in the new world? Who pays?
- And finally, what do we do about *maintenance*? Who is responsible for the maintenance of knowledge repositories or ontologies? And how do we prevent those people injecting their own biases into the mix?

To conclude, let us consider two models of economic activity (cf Fuller 2002, 36-44). *Profit seeking* is the performance of work to realise future benefits; I invest my time now to enable economic activity to take place in the future. This might be designing a machine, or writing some program, or inventing a procedure. Profit seeking, in other words, is *productive*. Contrast that with *rent seeking*, seeking benefit from past work. The trick is to be in a position to *prevent* productive activity from taking place. Corruption is one of the worst types of rent seeking, where an official, having managed to get himself a key job in the past, now uses it to cream off bribes from those who need to get round the regulations. However, many types of rent seeking are legitimate; nevertheless, they all flourish when productive activity can be retarded.

If we think about rent-seeking and profit-seeking in a knowledge market, we can see two possible futures for the SW. The vision of Tim Berners-Lee, the vision that most researchers in the area have, is that of enabling new knowledge-based activity, economic and otherwise, of promoting research, and of boosting the circulation of information.

On the other hand, suppose rigid ontologies ossify outmoded conceptualisations of domains. In that case, certain viewpoints within society, and within organisations, may become privileged. They could use this privilege to their own advantage, and will also act to defend those privileges. Knowledge is power, as they say, and if we find difficulty representing all types of knowledge, we risk being party to a skewed and unproductive distribution of power.

That is not necessarily reason to be pessimistic that the vision of the SW will be effaced by the nightmare. But we should be wary of the dramatic claims that some make about the SW. We shouldn't try to disguise the important social dimension to knowledge. We cannot adopt an epistemological stance free of politics.

What can we do in future? The main thing is to be alert to potential pitfalls of the technology. We can't predict the future; technological determinism is always a big mistake. But we must try to capture knowledge of diverse types from heterogeneous sources, support reasoning that is as scruffy as we can bear, support the processes of debate and disagreement, and automate ontology construction, V&V, integration etc, as far as possible.

These are all difficult and messy research problems. But the technology will benefit in the end.

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