Aligning Technical and Human Infrastructures in the Semantic Web: a socio-technical perspective

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Abstract. The paper offers a social science perspective on some of the assumptions and abstractions implicit in the semantic web vision in one bio-medical domain. The focus here is on the more persistent semantic and systemic alignment issues in the context of neuro-psychiatric disease, as experienced by Grid projects working in this domain in the UK, EU and US, where the opportunities and the challenges of integration have been particularly evident.

Tempering the Vision

Cyberinfrastructure promises a vision of seamless data sharing, using the semantic web as 'an enabling layer where data can be represented in a format that can be read by distributed human and machine users' (Gruber 2005, 2007). Ontologies play a role in this, and provide additionally for reasoning across these data sets based on a shared specification of classes, properties, attributes, and relations representing a specific view of a domain. In this regard, the semantic web provides the mediating layer in a socio-technical complex, aligning technical systems that are deterministic with human systems which are less so. (Joslyn 2000).

One role of visions is to provide an orientation for the design of semantic applications to support research and practice; they can sometimes, however, be blind to the sorts of practical problems on the ground which impact on its realization (Hartswood et al 2006). The experience of attempting to achieve this in practice can provided interesting insights on the ways in which software abstractions (Dourish 2001; Jha 2007) shape or constrain the ways in which data is shared across communities of practice where heterogeneity, volatility and uncertainty are increasingly a factor. Systems reflect the expectations, assumptions and abstractions of designers and users. Software design has been described as 'covert philosophy' (Agre 1997), based on abstractions that can significantly change processes and outcomes.We look at the challenges to some of the assumptions and expectations implicit in the design of semantic web infrastructure for data integration in a specific disease domain (schizophrenia), where multiple UK, EU and US Grids were developing ontologies wished to roadmap the issues, and consider strategies for future data-sharing in the wider European context.[1]

The paper takes a social science perspective on some of the assumptions and abstractions implicit in the vision as they impact on one domain. We highlight a range of recurring socio-technical and sometimes socio-political issues encountered by multiple Grid projects in the bio-medical domain, and some of the emerging strategies being used to address these. We suggest that there are emerging trends in the way technical and human infrastructures are being aligned in the semantic web to support future infrastructure for data sharing and data integration in e-Social Science and e-Science. In particular we point to a move from system centric to user centric models of alignment driven by the benefits of leveraging local expertise and agency. There were numerous examples of the use of (or need for) local input in ensuring the quality, currency and usability of services. These are also very evident in other distributed environments that are volatile or dynamic such as eBusiness (Sawhney 2001: Lloyd 2003) where speed and accuracy of response is at a premium for commercial or safety reasons.

We chose to ground our discussion in the bio-medical domain in this case for a number of reasons. It represents one of the flagship applications for cyberinfrastructure where some of these (often implicit) assumptions will be tested in practice on a large scale. The workshop series provided a unique opportunity to identify issues with several project teams seeking inter-operability in the same domain through the stages in data integration 'life-cycle' from data collection and coding, to analysis and use in research and clinical practice.

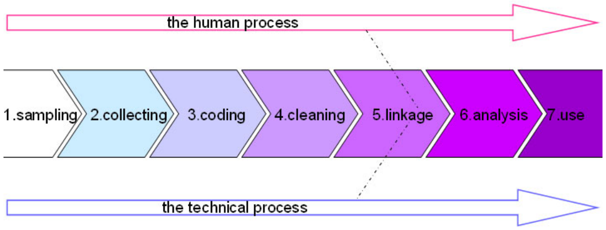

Figure 1. Socio-technical alignment in eHealth.

Many of these problems raised at different stages derived from assumptions about how the gap between technical and distributed human information systems could be bridged by semantic services – in the selection, collection, publishing, coding, cleaning, representation, analysis and use of distributed data from disparate origins and contexts of

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[1] Re-use or Re-invention - a Roadmap for Data Integration (Schizophrenia as a Test Case) 27 Nov. 2006 UK eScience Centre http://www.nesc.ac.uk/action/esi/contribution.cfm?Title=709

use. Where there were significant or unexpected problems, these were typically associated with data quality and usability, and therefore with the sustainability and continued funding of Grid-enable approaches. As such they are important challenges for the core aims of large scale data sharing.

Vision and Reality: Socio-technical Issues in Data Sharing

Duguid (2003) refers to the 'social life of information' and in the context of eHealth data, there were recurrent scenarios where particular alignments/misalignments impacted on this at discrete stages in the cycle.

Assumptions about Data Collection

Many of the 'common sense' assumptions made when scaling up systems for use across multiple sites were neither 'common' nor 'sensible' when applied to different community contexts., and many of the local practices behind existing codes and standards highlighted the and social, cultural and often political processes that shaped them (Bowker and Star, 2000).

Known error rates of 30% were reported as not uncommon , and when unpicked, often reflected poor alignment of the virtual process with the real processes in practice in different sites, por poor coordination of the process itself across sites. This raises serious questions about conclusions from multi-site studies involving small effects. From the perspective of the significant investment involved, it also impacts on the achievement of the quality of data needed to ensure uptake and sustainability.

The workshop allowed for exchange of useful strategies for minimizing some of these errors, such as the use of wireless notepads for data collection by research nurses, where mismatches with data already held on data bases could be checked while nurse and volunteer were still there. Despite this however, it was striking to what extent shared protocols and templates were differently interpreted and used.

As an example, protocols for drawing around a region of interest in the same set of brain scans were found to generate different scores on volume by different groups. It transpired that one group drew inside the line, and another drew outside the line. Significantly, the error became apparent through informal exchanges by teams on the same site becoming aware that they were getting different results from use of the same data and the same protocol. In multi-site studies it is virtually impossible to differentiate between real effects, and those introduced by such differences. The opportunities for identifying and addressing such errors through local interaction were a significant missing element in the equation within and between Grid projects in the same domain.

Assumptions about the comparability of data sets were often predicated on assumptions about the potential to harmonize processes and tools. In the context of our example, sharing data on schizophrenia, there were a range of tools, techniques and formats for capturing aspects of the same structure or process. Many of the significant factors that could affect data quality were only apparent in the course of face to face discussion – for example – that magnetic resonance imaging scanners for brain scans were serviced monthly – with slight changes in calibration sufficient to make data invalid. Local knowledge and agency was often central to data quality in the face of unpredictable local changes.

Assumptions about Coding and Metadata

The definition of core metadata reflected the difficulties associated with

- variance across groups with diverse requirements (heterogeneity)
- variance of requirements for different purposes and at different times (volatility)
- defining requirements 'en blanco'

Clinicians were often unfamiliar with the Grid concept, and found it hard to provide requirements for multi-site working in a hazy future scenario. As a result, there were often late additions to core metadata as the requirements became apparent from prototypes. Late additions were often the focus of hostilities between technical design teams (Pleiter 2006), clinicians and researchers, trading off the cost of later changes in the software design against the cost of producing a system that would not meet the needs of particular user groups. So called 'wicked' (Rittel 1972) problems of this nature are familiar in other distributed systems.

Often the need for new metadata only became apparent to clinicians after the development and clinical testing of a tangible first prototype and discussion of anomalies with known datasets (Geddes, 2006). The use of early prototypes or even mockups provided a vehicle for early community engagement in a number of groups in what one developer described as 'giving them something to hate'. These are particular challenges for the usability of future semantic Grid infrastructure, given the speed with which new knowledge and new conceptualizations now evolve and must be accommodated in some way in a shared model.

Role of Local Knowledge and Agency in Data Quality and Usability

What was most consistently striking was the extent to which the identification and the elimination of significant errors were often dependent on the leverage of local knowledge and agency and opportunistic communication between user groups. Assumptions about the potential of shared protocols, data cleaning software, and other approaches to managing data quality were limited in practice. Unpicking these examples suggested that – as many social networking applications have demonstrated – the distributed human resource can be leveraged to enhance the quality, currency and local usability of information as an integral part of system design.

Some of the problems identified suggested that the elimination of many of these informal exchange processes in large-scale distributed systems and other virtual organisations can generate high levels of errors, many of which would not be evident from inspection of the data alone. Quality assurance mechanisms may identify unexpected data values, but cannot provide information on the likely causes. For example, the differences in resting heart rate between two populations in one of the studies was initially though to reflect higher rates of blood pressure between samples in different cities, but local knowledge gleaned from research nurses highlighted the fact that the lift in one hospital had broken, and patients were tested after climbing several flights of stairs before being tested for 'resting' heart rate. Again, this was an accidental discovery arising from an anomaly being discussed while one of the nurses was present and able to draw on this knowledge of the local context.

Assumptions about shared domain models

Cyberinfrastructure now provides access to a vast array of large, heterogeneous and multi-dimensional data from multiple sources, and across multiple scales. In the context of our exemplar, data at molecular level on synaptic proteins involved in human mental illness, such as schizophrenia, is even more valuable when integrated with scanning data, and genetic data. Yet again, however, this vision requires convergence on a common model for mapping data from different sites, and at different levels of granularity.

For some of the design teams, there was an implicit assumption that the domain was 'out there' and the challenge was to facilitate the documentation and the clarification of this at a relevant level of detail and in an acceptable format. While there was some acceptance of the fact that concepts of disease would vary, and compromise was required, there was an underestimation of the extent to which tangible physical structures were differently conceptualized, bounded or defined in relation to other structures for specific purposes. On closer examination these were not merely semantic differences. Often they reflected the different practical purposes for which this information was required, the context of use, and the power of particular groups to shape adoption in practice within communities.

The work of the Ontogenesis and the NCeSS Ontology workshops (Lin et al 2007) provided important research routines in this contexts for facilitating understanding of this as a socio-technical process of the kind already described by Bowker and Star (2000). Participatory observation at these events and sites is in itself a viable research methods for understanding how ontologies are developed and built. An Ontogenesis network[2] workshop led by Manchester University recently provided some interesting examples of this derived from the definition of geographical domains for use in UK Ordnance Survey Maps. Representing concepts such as river and lake turned out to be just as socially constructed and purpose specific as many disease concepts. The criteria for water boards measuring quality or quantity were based on different criteria from those of anglers, tourists boards, geographers, scientists or historians. The use of metrics on the basis of relative size or shape was not sufficient in themselves. It was apparent also that the choice of a particular definition would in itself enact the adoption of this as the meaning in general practice, as the Ordnance Survey Map provides benchmark for many other applications. In short, the construction of shared meanings, even in apparently tangible domains such as this, appeared to have a performative element to it (Mackenzie, 2006), reflecting the ability of different stakeholders to shape adoption in practice. Disease domains combine the difficulty of achieving consensus on both the spatial modeling of the human body and defining shared concepts of disease that diverge across communities and over time.

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[2] www.ontonet.org

Aligning socially and logically constructed models

Ontologies are socio-technical systems par excellence, mediating technical and social models of a domain to support data sharing by human and machine agents. One evident barrier in specific disease domains such as schizophrenia was the reported difficulty of transposing many current medical concepts used by clinicians into a form that was amenable to analysis by formal logic in an ontology. Rector (2001) and Dupre (2006) highlight the inconsistencies in many of our current concepts of biological entities themselves, and the difficulty therefore of achieving logically consistent shared models of spatio-anatomical elements, borders and relationships to support data integration. Problems reported by ontologists in a number of projects suggested that biological and bio-medical concepts often had socially constructed attributes that did not lend themselves to shared ontological representation using formal logic (Martone, 2004). Bodenreider (2004) recently described the problem as the 'intrusion of the epistemological in the ontological'. In other words, some of the evidence suggests that the domain is not 'out there' ready to be translated but require support for communities to construct shared understandings.

A Spectrum of Approaches to Socio-technical Alignment

There are evidently many tensions between the technical ideal of a stable, interoperable information infrastructure and the view of research based knowledge as a continually evolving, mutually constructed (and often disputed) entity. Early Grid prototypes in real domains such as allow us to unpick the implications of these assumptions and design abstractions in practice, and consider how different alignments of technical and distributed human information systems enhance or undermine the quality and usability of cyberinfrastructure in real world contexts.

One Size Fits All

While the early vision of the semantic web implied the possibility of a 'one world' view, this is increasingly under threat in theory and in practice. Goguen (2005) points out that many ontologists still 'seem to believe in the possibility of a single unified ontology that attracts consensus because it "reflects the real underlying reality" of a domain'. If the need for conceptual diversity is accepted, it then follows in his view that knowledge engineering 'should seek ways to support it, rather than ways to overcome, suppress, or subvert it.' He suggests that the practical implications include (a) support for multiple evolving ontologies for single domains, and (b) provision of tools to help construct partial mappings. (See next section)

A variation on the 'one world view' is the use of the collaboratory to shape/construct common understandings where possible, and to minimize diversity through collaboration, critical mass and open access. The collaboratory[3] approach (Olson et al; Kling 2003) is well established in e-Science and e-Social Science as a means of supporting enhanced inter-operability by open access to resources and tools already developed. Open Source strategies such as this have emerged rapidly in these domains (Metcalfe 2007; Feller

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[3] The US Bio-informatics Research Network (BIRN) www.nbirn.net actively promote this approach

2007). In the context of our example case, there are now sustainable working partnerships using the BirnLex and Bonfire resource to build OWL ontologies and further joint proposals are explicitly designed to include some harmonization with the BIRN project. In a high risk, high cost context where it is difficult to predict the future, facilitation of a critical mass of resource and participation can provide a means of shaping adoption and use.

Core and local approaches

In some systems, the approach to this problem has been to separate out the core areas that can most easily/ usefully be standardized in machine readable format, and to allow a range of approaches to evolve 'at the edge' in an evolutionary manner around different views and different (often transient) purposes. This was highlighted in the NCeSS Agenda Setting Workshop on Building Ontologies for Humanities and Social Sciences[4]. Within this, Policy Grid (Edwards, 2007) provided a good example of the use of a core ontology with user based 'folksonomies' using tags to better leverage the technical and the human resource. Gruber (2005, 2007) suggests two approaches to integrating ontologies and Web 2.0 tags.[5] For social science applications, where the dynamic, evolving and socially constructed nature of concepts is of the essence this is an approach which seems more in line with current practice.

Often, as Goguen (2005) suggests, multiple purpose specific ontologies may be required, and then mediation tools provide a further means of achieving alignment, though participants highlighting a range of problems in achieving this across multiple sites and databases.

Ontologies can be considered, in light of Suchman's (2007) work, as technological infrastructures of objects that are 'imaginatively and materially reconfigured', and where the ontology development process involves diverse actors and artefacts. There is also a need for opportunities to tease out the ontology development process itself, and look more closely at 'the rhetorics and practices that often obscure the performative nature of both persons and things' (Suchman, 2007). The UK Ontogenesis network[6] and the US-based Ontolog forum[7] recently raised many of these issues as both challenges and opportunities, where Gruber suggests that 'tagging data offered a window into the intersection of formal reasoning (logical inference, database query processing, linguistic parsing) and semi-structured data with context-dependent semantics (labels and groupings of content, people's online identities)'

Local: Core / Bottom up

Motta (2007) suggests that in the next generation of semantic web applications there will be a move from the concept of a centrally designed, monolithic ontology towards more automatic integration of ontology fragments, sourced from the semantic web to meet transient user needs. He suggests that

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[4] http://www.ncess.ac.uk/events/ASW/ontologies/

[5] Examples such as Del.icio.us, Newsvine, LinkedIn

[6] http://www.ontonet.org/

[7] http://ontolog.cim3.net/

'the next generation of semantic web applications will aggregate data in a much more dynamic fashion, automatically identifying the semantic resources relevant to the current user need, doing away with the single ontology assumption and performing both ontology mapping and co-reference resolution on the fly. Hence, in this scenario the emphasis shifts from developing a centrally designed, monolithic ontology towards an automatic integration of ontology fragments, sourced from the semantic web.' (Motta, 2007)

The diversity of user requirements has been seen as a challenge to the vision of interoperability, but as an opportunity to leverage local knowledge to advantage in others, such as social networking sites for example.

An Evolving Vision

As research moves from research prototype to sustainable service mode, the emphasis on the cost quality and usability (Procter 2006) of these systems has highlighted the benefits of aligning technical and social systems in diverse ways. Parashar (2005) and Jha (2007) mention the evolution of programming models and abstractions in the technical infrastructure of Grid applications, where heterogeneity and dynamic change are increasingly factors in the design concepts. We argue that similar patterns are now emerging in semantic web applications.

The costs, risks and benefits inherent in different design paradigms will be differently distributed across different stakeholders. What is not clear in many projects, is how these decisions should be made, when, where and by what means. This was most evident initially in ethical and legal aspects of data integration, and again, here, there ability to scale technical infrastructure was not matched by support for the development of ethical and legal arrangements. There was limited evidence of concern with the generation of the community and the coordination infrastructures which can coordinate and sustain this. 'shared spaces' (Nonaka, 2001) in Grid collaborations.

Cyberinfrastructure is often portrayed as a vehicle for knowledge discovery through the integration of data on a massive scale. While this is arguably the basis for knowledge discovery in contexts where the scale of computation and disparity of formats is the principal barrier this varies across disciplines. The nature of knowledge discovery in others, particularly social science, is based on the ongoing reconfiguration of distributed knowledge, information and experience through debate. Here diversity and change are the essence of the process, rather than an inconvenient aspect of it. It is in eSocial Science and eBusiness applications that this tension is most evident, and where some of the most innovative models have been most rapidly developed, as for example in social networking sites and other Web 2.0 applications.

Some authors such as Paranash (2001) and Jha (2007) suggest there is a need for new programming abstractions, better able to deal with heterogeneity and diversity, much as business models were obliged to mirror the dynamics of distributed global e-Business markets. Joslyn (2000) and Segel (2001) draw on abstractions from the design of coupled systems in nature, and suggest models for aligning fairly stable technical infrastructures synergistically with dynamic and human infrastructures in synergistic ways.

Conclusion

A sustainable vision of seamless data-sharing may ultimately derive from design that takes more account of the critical interfaces between technical and human information systems. The design of social networking sites has successfully demonstrated the value of effective socio-technical alignment strategies appropriate for heterogeneous and distributed systems. Local agency, when incorporated into the wider design concept, is increasingly seen as a resource for maintaining the quality, currency and usability of locally generated data, and as a source of creative innovation in distributed networks (Sawhney 2001; Berners-Lee 2007). The growing emphasis on quality, usability and sustainability seems likely to foster increasing interest in the design abstractions that deal with the leverage of both technical and distributed human resources to achieve this. The e Social Science community provides a core resource for documenting and also scaffolding infrastructure building (Procter (2007).

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