Layered Information Modeling and a Knowledge Organization Paradigm: Inherent Classification and the Design of Interoperable Systems

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Abstract
In knowledge technology work, as expressed by the scope of this conference, there are a number of communities, each uncovering new methods, theories, and practices. The Library and Information Science (LIS) community is one such community. This community, through tradition and innovation, theories and practice, organizes knowledge and develops knowledge technologies formed by iterative research hewn to the values of equal access and discovery for all. The Information Modeling community is another contributor to knowledge technologies. It concerns itself with the construction of symbolic models that capture the meaning of information and organize it in ways that are computer-based, but human understandable. A recent paper that examines certain assumptions in information modeling builds a bridge between these two communities, offering a forum for a discussion on common aims from a common perspective.

In a June 2000 article, Parsons and Wand separate classes from instances in information modeling in order to free instances from what they call the "tyranny" of classes. They attribute a number of problems in information modeling to *inherent classification* – or the disregard for the fact that instances can be conceptualized independent of any class assignment. By faceting instances from classes, Parsons and Wand strike a sonorous chord with classification theory as understood in LIS. In the practice community and in the publications of LIS, faceted classification has shifted the paradigm of knowledge organization theory in the twentieth century. Here, with the proposal of *inherent classification* and the resulting *layered information modeling*, a clear line joins both the LIS classification theory community and the information modeling community. Both communities have their eyes turned toward networked resource discovery, and with this conceptual conjunction a new paradigmatic conversation can take place.

Parsons and Wand propose that the *layered information model* can facilitate schema integration, schema evolution, and interoperability. These three spheres in information modeling have their own connotation, but are not distant from the aims of classification research in LIS. In this new conceptual conjunction, established by Parsons and Ward, information modeling through the *layered information model*, can expand the horizons of classification theory beyond LIS, promoting a cross-fertilization of ideas on the interoperability of subject access tools like classification schemes, thesauri, taxonomies, and ontologies.

This paper examines the common ground between *the layered information model* and faceted classification, establishing a vocabulary and outlining some common principles. It then turns to the issue of schema and the horizons of conventional classification and the differences between Information Modeling and Library and Information Science. Finally, a framework is

proposed that deploys an interpretation of the *layered information modeling* approach in a knowledge technologies context. In order to design subject access systems that will integrate, evolve and interoperate in a networked environment, knowledge organization specialists must consider a semantic *class independence* like Parsons and Wand propose for information modeling.

1 Introduction: Communities and Context

In knowledge technology work, as expressed by the scope of this conference, there are a number of communities, each uncovering new methods, theories, and practices. The Library and Information Science (LIS) community is one such community. This community, through tradition and innovation, theories and practice, organizes knowledge and develops knowledge technologies formed by iterative research stitched to the values of equal access and discovery for all. The Information Modeling (IM) community is another contributor to knowledge technologies. It concerns itself with the construction of symbolic models that capture the meaning of information and organize it in ways that are computer-based, but human understandable.

Exchanging vocabulary across discourse communities is a difficult task. It sometimes seems even more difficult the closer the communities are in topic. This is true in the study of information. Many different discourse communities are coming to study this thing called information. LIS and IM are two such groups, but there are others. And this population will continue to grow and diversify. In order to not duplicate efforts, and in order to advance the state of research, in order to promote successful implementation in these areas, we must be able to talk to one another. Language as it shapes our thoughts must not be so rigid, or encased so as to hinder communication rather than help it. In this particular case, Information Modeling and Library and Information Science have both reached segments of what could be close to a common conceptual framework. The challenge is now to see what can be implemented from a common perspective and to see if this common perspective will shape future research and learning.

It is obvious that these groups, IM and LIS, have different histories, purposes, and personalities. Each has grown in a trajectory that allows them to speak authoritatively on how information should be modeled or classified. Furthermore each has done so, with specific purposes in mind. For example Library and Information Science has looked to users to guide the design of systems, as well as services for those systems. An example of this is the reference desk, where professionals wait to interpret questions, negotiate the information need with their knowledge of sources, and fulfill information needs based on texts and other resources available to that reference librarian. This user-driven system has moved to the web with the focus in LIS schools on usability concerns of interfaces, databases displays, and directories of selected information resources.

The personalities at work in both Information Modeling and Library and Information Science consist of a spectrum of people and professions. Scholars in both fields learn, cultivate, and contribute to a language or discourse that helps solidify, disambiguate, and point to concepts that are either unique to the discipline, or illustrate a unique perspective on that concept. For example the word class, as we will see, exists in both Information Modeling and in Library and Information Science, but is defined differently. Each of these fields produces professionals as well. Not everyone who builds database schemas is a scholar. Similarly, not everyone who works in any kind of information center (corporate library, on an intranet team, as an information broker), is a scholar. These IM professionals and LIS professionals shape discourse as well. And their interpretations, innovations, and implementations of these terms and concepts shape the field, perhaps even more so, than those who publish from the academy.

Thus, with seemingly ubiquitous information technology and many knowledge organization problems that stem from abundant information access, many tributaries find their way to this research sea. And it is in such a research sea, that terms must be reconciled, so that ideas can intermingle and so that collaboration is fostered not forgotten.

Parsons and Wand have laid the groundwork, conceptually for something called *layered information modeling*. I am here today to offer what I can to this area of study both conceptually and terminologically.

1.1 Conceptual Problems in Information Modeling

Parsons and Wand propose a model of information modeling that frees instances from the tyranny of classes (Parsons and Wand, 2001). Instances by their definition are "specific things in a domain of interest (entities, objects, etc.)" that are represented in the context of classes. Classes are referred to in the Information Modeling domain variously as "entity types, categories, or kinds". The example they give is: "when one speaks of an individual (e.g., Jane Doe), one invariably provides, either explicitly or implicitly, a context or classification (e.g., Jane Doe as Customer, Jane Doe as Employee)" (Parsons and Wand, 2001). Jane Doe is the *instance*, Employee is a *class*. However, as you can see in this example the *instance* Jane Doe can belong to more than one class. The *instance* can belong to both the *class* Employee and the *class* Customer. In Information Modeling, Jane Doe does not exist without belonging to some class. Parsons and Wand see this as a problem. That is, because Jane Doe has to belong to one of these classes she is subject to inherent classification.

There are four conceptual problems with *inherent classification* outlined by Parsons and Wand. They are the *multiple classification problem*, the *view integration problem,* the *schema evolution problem,* and the *interoperability problem.*

The Multiple Classification Problem

This problem arises when one thing (an instance) can occupy more than class. The example given by Parsons and Wand is of a person, who can be an engineer, a customer, and a shareholder. Whether this is really classification or not, is a question Library and Information Science would have. As we will see below, LIS has some strict definitions of classification. However, this is only one problem outlined by Parsons and Wand. Though this has been addressed in IM literature related to *roles* and *preferred* classes, there appears, to the authors, no systematic theoretical basis for making these distinctions. Thus, this previous work does not adequately address the problem of multiple classification. Their instance-based model does so.

The View Integration Problem or the Schema Integration Problem

When integrating different user views on a domain, the unified domain has to reconcile how different user views portion different segments of reality. Again, the person in one view is an Engineer only, yet in another view this person is three things: engineer, customer, and shareholder. These views, if the schema is to be integrated, must sometimes lose meaning as the global, or integrated, view must reign over the individual views of the domain. Thus the user must adapt their view of the domain to the global view. Many problems can stem from such assimilation. An instance-based model, say Parsons and Wand, alleviates the need to assimilate in such a way.

The Schema Evolution Problem
Schemas are constructed at a point in time. The structure of that schema represents the "snapshot" (Parsons and Wand, 2000) of the domain at that point in time. It is inevitable however, that the world-views on domains change. Thus schemas should change. They must evolve. If instances are tied to classes, evolution is a complicated and laborious process.

The Interoperability Problem
Exchanging information between independent information systems is known as interoperability. If classes dictate what instances are grouped together, or what properties are expressed in one system, then transferring instances between two systems that define classes differently results in a loss of information. Further, it may not be possible to create interoperability between two such systems. Parsons and Wand address these issues with an instance based model of information modeling. Interoperability is the key to the semantic web and federating distributed digital libraries. If Parsons and Wand have an answer, we want to know what it is. A fuller discussion of interoperability comes later in this paper.

1.2 Terms of Art
Information Modeling and Library and Information Science each have their terms of art. Though the terms may be similar on the surface, the purpose and hence, definitions in action, of these terms vary. What follows is a brief outline of the term as defined by Parsons and Wand for Information Modeling (IM) and a collection of authors for Library and Information Science (LIS).

1.2.1 Information Modeling
Information Modeling is the set of activities related to modeling a domain for the purpose of developing an information system. This includes the notions of data modeling, semantic modeling, and conceptual modeling, (Parsons and Wand, 2000). In order to talk about what this domain offers that is unique and similar to Library and Information Science we must outline vocabulary.

Instances
According to Parsons and Wand, instances in their instance-based model would use only "one global identifier for every instance. This amounts to having a global instance identity..., and each identifier serves as a surrogate designating the existence of a corresponding real-world thing," (Parsons and Wand, 2001). This is contrasted against the practice of "class-based identifiers" or "keys, (Parsons and Wand, 2001). The example of a class-based identifier is an identifier like Social Security Number, which presumes the class, "resident of some country, (Parsons and Wand, 2001). An instance in the model is a thing, an object, or an entity (automobile). It is linked on the same layer with its properties (e.g. has color). Management of each of these atoms of information forms the first step of an instance-based model of information modeling.

Properties

Parson and Wand discuss *properties,* in the frame of the philosophical sub-discipline of ontology[1]. Properties are those terms used to describe things. There are no things without properties and properties are always attached to things. Further, no two things contain the same set of properties.

Classes

Classes are sets of things possessing a finite set of common properties. The existence of classes follows and assumes the prior existence of instances[2] and their properties.[3]

Classification is a phenomenon that is studied in many disciplines, for many purposes. Parsons and Wand's definition of classification, borrowed from Bunge (1977), is the classical definition of classification, where classes are formed by grouping properties. This has come to be called categorization in LIS. Without going into too much detail, it suffices to say that, though they define classification differently, Parsons and Wand operate from the same opinion as many researchers in LIS, that classes are constructed, not inherent in the natural world. This follows the work done by Lakoff (1987).[4]

It is through this definition of classes, and this specific distinction between instances and classes, the distinction between natural world and a human constructed world, where we see the differences between IM and LIS surface. LIS is very concerned with concepts, not just real-world entities. How would *concepts* fit into Parsons and Wand's layered information model?

Schema

A schema is a fixed structure of classes (Parsons and Wand, 2000, p. 231). It contains the attributes and linkages of these classes. Thus, it is the collection of the instances, properties and their relationships at a given point in time.

Inherent classification

Inherent classification is an assumption in information modeling that specific things in the domain of interest can be referred to only as instances of classes (Parsons and Wand, 2000, p. 229).

1.2.2 Library and Information Science

Classes

A class in LIS is a ranked group emergent after assortment into groups (Ranganathan, 1967). Other authors in the field, (Beghtol, 1998) use a traditional definition of classification systems as those that create classes that are mutually exclusive and jointly exhaustive. Thus, each class

[1] Ontology is the branch of philosophy that deals the order and structure of reality in the broadest sense possible (Parsons and Wand, 2000)

[2] or things. They are used interchangeably.

[3] It is by *Laws* that some properties are grouped. Parsons and Wand state: "Things can have one or several properties in common. Furthermore, their properties might be subject to the same laws. This gives rise to the concept of *class*." They also state regarding Laws, "'all entities satisfy some laws' [Bunge, 1977, p.77]. Laws are defined in terms of relations between properties. A particular form of law is *precedence*. (Parsons and Wand, 2000, p. 237) [emphasis theirs].

[4] And it is through this definition of classes and this specific distinction between instances and classes, the distinction between natural world and a human constructed world, where we see the differences between IM and LIS surface. LIS is very concerned with concepts, not just real-world entities. How would concepts fit into Parsons and Wand's layered information model?

would be a representation of a point on a line in a single dimension where a multidimensional space (the collection of concepts) was translated into a class. This is the strict definition of classification.

It is worth noting that much of LIS classification deals with subject classification. This act of classifying the universe of subjects, or all the subjects of a given sphere of knowledge, is work in the intangible. There are no real-world instances in this case in LIS.

Facets

"A generic term used to denote any component," (Ranganathan, 1967). A facet can also be defined as "any of the various categories into which a given class may be divided" (Library Corporation, 1999). Facets, though on the surface, may look like properties are the range of classes in their entirety. That is, there are no accidental facets in a class in LIS classification, as there might be in a classical interpretation of classification by properties. Parsons and Wand use the classical interpretation of classification.

Scheme for Classification/Controlled Vocabulary

A scheme for classification shows the coherent sequence of classes. This illustrates relationships and order between classes, (Ranganathan, 1967).

Hierarchical Force

The principle of hierarchical force states that the attributes of a class apply to all the subdivisions of that class.[5]

1.3 Common Ground

As viewed through the texts of Parsons and Wand, Information Modeling and Library and Information Science share the idea that classes[6] force meaning on their constituents. The corollary from this is also a shared concept. That is, we must be able to recognize atomic units before we recognize their shared likeness and therefore classes. Thus for Information Modeling we must recognize instances and their properties before we recognize classes, and for Library and Information Science we must recognize facets before we recognize classes.

2 It's in the details: instances, facets, and other pieces of the information puzzle

Though IM and LIS share some common ground, as outlined above, the question remains, what are instances, facets, and the like? In order to make sense of the common ground between these two communities, in order to find out how and where these domains overlap, we must first get to the heart of these terms. What do they refer to?

Instance in detail

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[5] This principle is used by bibliographic classification systems like the Dewey Decimal Classification. This is outlined by the Library Corporation (1999).

[6] It should be emphasized here that the term classes signifies the fact that we are concerned with *surrogates* of documents, or only limited representations of people and their various relationships or roles. These *surrogates* necessarily hide because they highlight only one aspect or a partial aspect of document or person. We are not concerned at all with full-text documents in this discussion. Much work has been done to discuss issues of vocabulary in full-text corpora. We are concerned with document or other representational *surrogates* here.

Instances are things, real-world things. The examples given by Parsons and Wand are automobiles, people, and students. Though these can be described by different properties and placed into different classes, they do not give themselves to lofty interpretation in each of these database systems. That is, they are explicitly real-world objects. This contrasts with most LIS facets, because there are an equal number of conceptual facets as real-world facets. Not every facet is a thing.

Facets in detail

In contrast, a facet is an atomic unit of a concept or concept collection. It is the lego-like piece of concepts, that once assembled constitute a class. They may or may not refer to real-world things. Further, facets can be isolates or subject in S. R. Ranganathan's subject classification theory. This allows a facet to be either a whole subject or parts of subjects, like History, blue, or child. And though facets can represent real-world objects like cars and professions, they are used in interpretive ways, for interpretive purposes.

3 Schemas and the horizons of conventional classification

The Interoperability Problem…again

Parsons and Wand discuss the interoperability problem as such: "The capacity to exchange information among independent information systems is known as interoperability. It can be difficult for systems to interoperate due to differences in their conceptual schemas (semantic interoperability). Hence, reconciling schema differences, either by developing a "federated schema" or mapping between distinct schemas, is necessary [Kim et al. 1995; Sheth and Larson 1990]. A significant part of such reconciliation is identifying correspondences between classes in two or more schemas. In this regard, the semantic interoperability problem is similar to the schema integration problem. For instance, two classes may have the same names but different meaning (e.g., defined in terms of different attributes). Alternatively, classes with different names may be essentially the same. Resolving such issues of the definition of classes in multiple systems is a prerequisite to the interoperation of these systems," (Parsons and Wand, 2000).

The problem of semantic interoperability guides the remaining sections of this paper. There are varieties of semantic interoperability. This paper will discuss semantic interoperability, switching languages, and subject access interoperability.

Semantic Interoperability

Semantic interoperability is a broad term, defined by Parsons and Wand as the sharing of conceptual schemas between two independent information systems. This term accounts for every type of conceptual schema sharing. This is a huge field that covers many types of conceptual schema analysis and exchange.

Switching

Switching languages date from about 1970. Since the advent of cooperative, yet distinct, specialized information centers, information professionals have tried to reconcile the differences between specialized controlled vocabularies, or thesauri. Researchers at the time (Neville, 1970), found that in order to reconcile three engineering thesauri from three different information centers a fourth switching language had to be constructed. Even then, that switching language had to account for at least 22 different types of variations of how concepts were represented by terms in that thesaurus.

Subject Access Interoperability
Subject access interoperability is a more narrow term and is related to switching languages. Subject access interoperability is the "state whereby different controlled vocabularies provide subject access to collections in a networked environment, beyond their own," (Tennis, forthcoming). There is a strong synergy between work in subject access interoperability and Parsons and Wand's layered information modeling. They share a design based on layers.

Layers
The structure proposed by Parsons and Wand is a layered one. They outline a two-layered approach. This approach has an instance model and a class model. The instance model contains at a minimum: instances, properties of instances, and precedence of the properties. The class model contains classes, definition given to classes, and information about what instances belong to what classes. By separating instances from classes interoperability is achieved for Parsons and Wand in this simple way: "agreement is needed only on the things that exist and their properties. Provided that such agreement can be achieved without first agreeing on the semantics of classes, the integration effort under an instance-based approach is strictly less than the effort required under a class-based approach," (Parsons and Wand, 2000, p. 248). With that said, Parsons and Wand state that "the two-tiered approach cannot completely eliminate the difficulties of semantic interoperability. There is still the need to agree on meaning of properties, and this can still be a significant problem. Furthermore, in operating on the database, users will use the classes; hence the intentions of the users have still to be interpreted," (Parsons and Wand, 2000, 249). They have achieved little more than passing the word car between systems.

(Semantic Space?)
Thus, the architecture of a two-layered information model allows us to transfer one of three meaningful objects between independent systems almost automatically. The remainder, properties and classes, we are told by Parsons and Wand, must be interpreted by the systems designers and the users. Rendering them un-interoperable.

(Things and concepts)
It is easier to see agreement on whether a car is a real-world-thing. However, a further complication can be illustrated as a simple rhetorical question: Is history a thing? It is a term in a database. It has properties. It goes into classes in various schemas. Is it an instance? Is it a thing? If so, *is* it as easy to transfer between two independent information systems as Parsons and Wand would have us suppose? Yet another logical complication follows. We might say that if all instances posses properties, and those properties must be interpreted, and if it is those properties that distinguish and make similar instances, then there is no point in attempting to share instances alone, without properties. The transfer of instances alone would result in the passing of meaningless tokens or stings of text that would demand interpretation by anyone using the system. Rendering semantic interoperability neither semantic, nor really interoperability.

4 Layers of the Layered Information Framework

With the advent of the networked world, information has been transferred in a more liquid state than ever before. I say liquid in that it is not transferred in a gaseous state, as spoken words are, and it is not transferred in a solid state the way hard-copy print documents move in a fixed form. In the digital world information takes the shape of its container - just like liquid. It conforms to the word document format. It conforms to the ACSII text format. It moves with the maximize and minimize function of your browser. Thus, when we look to shaping the containers of this liquid information that can then be fluidly transferred across the network, we look to structures that are not quite fluid, but that are not solid either. We want structure yet we want flexibility. Those requirements bring us to metadata, and more specifically to flexible metadata. But what makes metadata flexible? What is it that metadata structure both gives shape to liquid information and is in turn permeable enough to let liquid information pass through? How does metadata help us with subject access interoperability?

The short answer is again, layers. The longer answer is many layers coupled with a design for creating a *semantic space*. As discussed above, there are a number of discourse communities examining the information society and information transfer. There exist many more than can be referenced in this paper. Then Parsons and Wand hit and missed the semantic interoperability mark. Though they were drawn to, and made use of, layers. These could be seen as one of the commonalities that undergird and provide foundation for fluid information transfer. It remains impossible to impose one solid framework on information flow. Simple examples can prove this to be commonsense. Writ large, humanity is not interested in unity in information flow. How many languages are there? What have happened to attempts to standardize languages, to construct artificial or universal languages, esperanto? In order to facilitate transfer between systems (socio-economic, political, or technical) we must build systems with layers. Semantic interoperability is no different. With such tools present, what can we build?

Semantic Web, or The Interoperability Problem…again…again

Current work on the Semantic Web, the next generation of the World Wide Web, is very concerned with interoperability. The word semantic means many things to many people. The word semantic requires interpretation. However, they have not yet successfully addressed the issue of interpretation in ontology construction. In their *Requirements for a Web Ontology Language: W3C Working Draft 07 March 2002* (W3C, 2002) they sketch a goal of ontology interoperability:

> **3.3 Ontology interoperability**
> Different ontologies may model the same concepts in different ways. The language should provide primitives for relating different representations, thus allowing data to be converted to different ontologies and enabling a "web of ontologies."
>
> **Supported Tasks:**
> Any use case in which data from different providers with different terminologies must be integrated.
>
> **Justification:**
> Although shared ontologies and ontology extension allow a certain degree of interoperability between different organizations and domains, there are often cases where there are multiple ways to model the same information. This may be due to differences in the perspectives of different organizations, different professions, different nationalities, etc. In order for machines to be able to

> integrate information that commits to heterogeneous ontologies, there need to be primitives that allow ontologies to map terms to their equivalents in other ontologies.
>
> **RDF Support:**
> RDF provides minimal support for interoperability by means of the rdfs:subClassOf and rdfs:subPropertyOf properties.

Library and Information Science, as well as a myriad of other disciplines would restate the Justification section. I can imagine it reading:

> **Justification:**
> Although shared ontologies and ontology extension allow a certain degree of interoperability between different organizations and domains, there *will always be* cases *that prove that there are an* ***infinite*** number of ways to model the same information. This *is* due to differences in the perspectives of different organizations, different professions, different nationalities, etc. In order for machines [aye there's there rub] to be able to integrate information [not knowledge] that commits to heterogeneous ontologies [such as language for example], there need to be primitives that allow ontologies to map [an impossibility according to Lancaster (1986)] terms to their equivalents in other ontologies.

Even with this editorial skepticism, the Semantic Web is possible. It must be. To barnacle the flow of information across such a massive network so that users seeking information can make meaning from metadata; that is the manifest destiny of clients and servers. *How* Semantic the Semantic Web can become by machines alone is another question. If we are to move interoperability into the realm of a knowledge technology problem, there need to be interpreters along the way. Further, the differences and fuzzy zones that make information what it is, need to retain their differentiation and their haze that allow the reader to make information for themselves.

4.1 Facets and How

How can scholars and professionals capitalize on the layer models and help contribute to the realization of the Semantic Web and like semantic interoperability problems? As I have argued elsewhere (Tennis, forthcoming) a layered model that first separates concepts, classes, and subjects, then fixes interpretive power into the domain of knowledge workers, all built on a faceted classification is one way to forge ahead. Without revealing too much, the abstract schematic or architectural building-blocks, of such a system looks like this.

[diagrams]

5 Conclusion

Two disciplines, Information Modeling and Library and Information Science, have approached the information problem from different angles, and each has generated a similar results: atomic units and layers. The problems that still plague interoperability are meaning and interpretation. What mechanisms are system designers of interoperable knowledge technologies going to provide their users? Will they take into account four problems outlined by Lancaster?

Layered information model is not necessary for every kind of information. A faceted classification is not necessary for every subject classification model. It is a tool among many in the toolbox. Ultimately the science of information modeling or classification can be interpreted as the science of representation or interpretation - as exact as it can be in the feeling of the moment. There is an aesthetic to such interpretation that escapes the most formal method of analysis or construction. Thus, with meaning playing fire and shadow with the would-be Platonic form of semantic interoperability, the tool for the task at hand is layers. Layers will allow the flexibility schema integration, evolution, and discourse community-specific views.

In order to design subject access systems that will integrate, evolve and interoperate in a networked environment, knowledge organization specialists must consider a layered information model that moves from passing instances to interpreting facets.

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