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Steps Toward a Socio-Technical Categorization Scheme for Communication and Information Standards

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ABSTRACT
Socio-technical systems continue to grow larger and more complex, comprising increasingly significant portions of contemporary society. Yet systematic understanding of interrelationships between social and technological elements remains elusive, even as computers and information systems proliferate. In this paper, we draw on ethnomethodology to distinguish several different kinds of processes through which communication and information are constituted. We discuss the distinctive properties of each in an effort to develop systematic understanding of basic elements of socio-technical systems. In particular, we offer a basic categorization of communication and information standards, noting the constitutive importance of their accompanying social practices. Implications for theory and practice are discussed.

Categories and Subject Descriptors
K.4.0 [**Computing Milieux**]: Computers and Society: General.

General Terms
Management, Design, Human Factors, Standardization, Theory.

Keywords
Communication, Information Standards, Social Practices, Socio-Technical Systems.

1. INTRODUCTION
"Socio-technical systems" have been studied for over 50 years, across a wide range of industries and utilizing a diverse collection of research methods. The basic term – originally coined by the Tavistock Institute's project on manufacturing systems – now typically encompasses information technology as well and is often used loosely to connote general integration and co-evolution of social and technical aspects of a productive enterprise. More systematic understanding of interrelationships between social and technological aspects has remained elusive throughout this time, especially with the proliferation of computers and information systems, to the point that numerous scholars stress how difficult it is to separate the technical from the social, and vice-versa ([4][40][53]), advocating eliminating the hyphen between "socio" and "technical" altogether.

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In this paper, we step away from that argument, and look instead at several different kinds of processes through which communication and information are constituted. We discuss each of these in detail and contrast them, offering what we propose are some basic steps toward developing systematic understanding of the component aspects of socio-technical systems. In particular, we offer a categorization of communication and information standards within and comprising a socio-technical system, noting the importance of their accompanying social practices.

2. MOTIVATION
Perhaps more than any other form of technical standards and standardization, the standards for, and standardization of, communication and information are particularly critical to the evolution of contemporary society. They comprise key forms of contemporary institutional regulation [5] and governance [23]. They also comprise an essential aspect of developing cyberinfrastructure [13][25], and its companion areas of eScience [48][55] and data science [30][50].

Standards for managing interoperability across information technologies and systems are necessarily formally computable. Meanwhile, human communication and sensemaking generally require forms of standards that support some degree of ambiguity and judgment [15][31][41][42][49][53][56]; in such cases, rigid data structures that facilitate machine reasoning are ill-suited, as social interaction and organizational coordination adhere to different logics and operate with different parameters than those for technical systems. And while the bulk of research on standards and standardization has historically focused on the macro level of analysis, recognition is growing that more attention is warranted toward these micro-level phenomena. As the social and technological become increasingly intertwined, the information structures that software engineers and data modelers encode into their systems need to do more than simply facilitate information processing by computers. Some of these structures must also encode or create information that can operate as standards for humans engaged in different – but interdependent – work practices across the enterprise, and the boundary-crossing process is not always simple or straightforward. In fact our work originated out of a recurring series of problems that information standards data modelers were having regarding the development of a set of information standards to be used across varying communities of practice [43]. Organizational and technological systems designers who take these challenges seriously must take both into account; understanding the workings of communication and information standards within such socio-technical systems is therefore critical.

We consequently assert that it is incumbent on designers of enterprise scale organizations and information systems to interweave design elements oriented towards human analysis and communication with those required for effective machine processing.[1] Our primary concern here is to compare and contrast standards that support effective human communication and sensemaking on the one hand, and those that support effective machine processing on the other. Practical outcomes of this work should assist designers of organizational routines, information systems and communication and information standards which facilitate coordination across organizations and enterprises.

Our work reflects the combined efforts of three contributors with unique backgrounds and areas of expertise: a technologist with experience developing user interfaces for large and complex information spaces, who also has a PhD in social science and is concerned with how information and communication technology is used; an internationally-recognized scholar of ethnomethodology and social interaction; and an information systems engineer with a PhD in mathematical graph theory and a growing understanding of ethnomethodology. The paper rests therefore on a somewhat unusual combination of socio-technical foundations. We believe that this unusual combination has something unique and worthwhile to offer.

3. COMMUNICATION AND INFORMATION STANDARDS

What is a standard? We consider a standard to be a pattern that persons (members of a social group or community) or machines follow in their communication with each other. Constitutive expectations furnish such patterns (Garfinkel 1963). We distinguish three such categories, differentiating them according to the primary actants [28] participating within each.

1) *Socially-interactive communication standards* – constitutive rules and preference orders for managing direct human to human verbal communication, which may reference commonly oriented groupings or categories of persons or objects
2) *Human oriented information standards* – for managing inscribed (written) objects mediating human communication regarding commonly shared groupings or categories of persons or objects
3) *Machine to machine information standards* – for inscribed (written) objects designed to support interoperability across information technologies

We present these types in the order in which they have developed historically. We draw a primary distinction between communication and information – emphasizing that basic communication (unmediated by information or communication technology) is carried out verbally and is therefore ephemeral, although such non-mediated communication may reference a group or collection of persistent objects. On the other hand, communication involving "information" is historically grounded in the use of digital media, occurring around the use of persistent artifacts bearing representational images.[2] When such representational artifacts are used, we refer to the representational artifacts bearing the images as "containing information," although as we will argue, this does not happen without constitutive social practices engaging those artifacts.

Our descriptions of these types of standards rest on two primary analytical constructs derived from the work of Harold Garfinkel and associates regarding talk-in-interaction.

Rules – Rules delineate allowable relationships between items referenced by or identified via the standard: how items referenced by a standard are organized within it, and how those differences are represented conceptually (and in some cases, digitally) and how they may legitimately be changed.

Category Membership - The process through which those items or events identified as "similar" by the rules are grouped together and associated with a certain meaning or term – how physical items or data instances can be paired with each other, and how it is determined which instances are related to which other instances, and how those relationships are characterized.

That objects, meanings and identities follow from constitutive rules we treat as the situated human standards of sense making. We then extend these themes in consideration of what happens when humans mediate their communication temporally and spatially through the use of informational artifacts, first considering those artifacts simply inscribed in relatively permanent fashion, and then those more readily manipulated in digital form via computerization.

4. SOCIALLY INTERACTIVE COMMUNICATION STANDARDS

We identify two main features of interaction relative to socially interactive (human to human) sensemaking, both derived from the study of ethnomethodology: sequencing and categorization. Regarding the former, a large body of research on conversation analysis (CA) has developed which is primarily concerned with turn-taking and preference orders in talk-in-interaction. Regarding the latter, work on membership categorization analysis [24][45] is quite relevant.

4.1 Rules Regarding Sequencing

Garfinkel [16] argues that indexicality is a property of all words and objects, although some words ("it" for instance) are more naturally indexical than others. From this perspective on human communication (i.e. in talk-in-interaction), meaning remains situated and must be constituted on each next occasion using rules. These rules regard sequence, and more specifically are comprised of orders of preference and orders of turns, which are sensemaking tools that are common across many situations. Garfinkel was the first to argue that sequential order was constitutive of meaning. In communicating, he said, people need to know how others have understood what was said [17]. This requires the development of a reflexive structure in which the next thing said offers an interpretation, or confirmation, of what was said previously, while also moving the conversation forward. While there are variations in form that occur within specific institutional settings – like courtrooms – or interview situations – those variations also make use of rules comprised of recognizable turn shapes and preference orders [8][20][33][46]. Thus, turntaking orders and preferences constitute a tool kit (skill set) that crosses many boundaries.

Building on Garfinkel's work, Conversation Analysis (CA) has developed as the study of recognizable ways (devices) through which communication can be ordered – by turns and according to

[1] Discussion of what is considered to constitute "effective" remains beyond the scope of current space limitations.

[2] We acknowledge that the distinction between communication and information may be considered fuzzier than indicated here. However, since the rise of the term "information" occurred concomitantly with the development of computers, we contend that the distinction remains useful for the current purposes.

specifiable orders of preference – in such a way that indexicality becomes a resource – rather than a problem. Harvey Sacks worked with co-authors Emmanuel Schegloff and Gail Jefferson [46] to develop these ideas of reflexivity and sequencing into the argument that there is a turn-taking system and an aligned set of preference orders. They argue that this turntaking system is used by people in both ordinary interaction and in technical worksite communication to create a recognizable order of turns at talk and this order in turn constitutes recognizable objects and meanings.

As Paul Grice [21] pointed out, clarification that does not advance a conversation entails an infinite regress. In order to do both – advance a conversation and clarify – an efficient use of indexicality is required. In originating this idea in 1948, Garfinkel referred to it as a sequential process with reflexive properties: each next thing said offers an interpretation/confirmation and can change the meaning of the last thing said (the prior turn). For example, a second turn that follows a first turn indicates how a first turn has been understood. Words in the second turn that would otherwise be ambiguous – indexical – take on a definite meaning in the relationship between turns. In so doing, they confirm a particular understanding of the first turn. For example: a first turn "Did you get to see the movie?" followed by a second turn "Saturday." And a different first turn "Are you going to see the movie?" followed by a second turn "Saturday." In both cases the word "Saturday" indicates an understanding of the first turn. But, the word Saturday indicates different days in each case – one past, one future. The specification of which is determined entirely by its relationship to the first turn.

The need for speakers to constantly orient toward the need to produce second turns – requires them to monitor the sensemaking efforts of others at all points. Producing short indexical turns that get their sense through specified relationships to other turns (and to orders of preference) is an efficient way for everyone to be sure at all points that they are both understanding and being understood. Through orders of turn-taking and preference orders, indexicality becomes a resource for producing certainty of meaning in conversation.

The argument then is that turn-taking as an order of sensemaking is necessary and ongoing. It is also a durable practice that takes place in many different contexts in similar ways. On this view when sense breaks down, it is because the order of turns and their preferences have either not been adhered to – or have not been produced in mutually recognizable forms. The rule-based standards of turn-taking and preference thus allow for the interactive creation (mutual construction) of objects that cross domains – "boundary objects" [2][51] – which can be transferred across boundaries of social groups as long as the rules and practices for constituting them remain essentially the same.

4.2 Membership Categorization

The idea of membership categorization devices developed during the course of the collaborative work of Garfinkel and Sacks, and further developed by Hester and Eglin [22]. Membership in a category is determined by the standards that define a group as a situated practice, or that are accepted by participants as constitutive of a situated practice. Rather than being defined by properties or classifications – membership categories are a natural outgrowth of the identities and things that are associated with a situated practice, and the characteristics associated with membership categories become associated with the practice.

For example, in conversation there is a rule – if two things can be heard as category members the rule or preference is to hear them that way. Speakers orient according to this rule, and this is how categories are disambiguated in ordinary interaction. It allows for a looseness of definition. It also allows a word or person to belong to many categories – just never at the same time, because in any actual utterance only one set of category relevancies can be mutually oriented. And if participants don't both (all) orient to the same, one or more of them will [need to] make a correction.

In their work on "*the reconsidered model of membership categorization analysis*," Housley & Fitzgerald [24, p.63] identify "three major concepts of MCA: namely, membership categorization devices, membership categories and category-bound activities." Noting that although membership categorization analysis was originally developed for categories of persons, they write that it is more recently being extended to socially constituted objects. The recognition of objects in categories is supported through the morality of social interaction [24, p. 66].

Such objects are significant relative to social practices in a variety of ways, especially because they are persistent in contrast to the ephemerality of talk-in-interaction. Thus whereas socially interactive (human to human) communication standards must be reflexive over time to maintain perdurance in memory [7], concrete objects do not require the same treatment to establish comparable psychological awareness, because they persist independently. Rather, they can be oriented toward as stable objects (even though they are constituted), thereby supporting the characterization of object-oriented category membership within human interactional communication as entailing structural form.[3] This property of material objects becomes even more significant when it is further extended below in the section on machine oriented information standards.

Material objects also serve as a primary basis for social practices. For example, while personal objects provide support for personal identity (of special importance to the elderly), categorical objects provide reminders of culturally appropriate actions, particularly in unfamiliar settings [36]. An unfamiliar room that is furnished with a desk, chair computer and phone would be readily recognized as an office and oriented to as such. Of course, relations with objects and settings differ across social groups and practices, and some socially oriented objects may serve as a symbol of the group [9]. Temporal relations are conveyed through an ordered sphere of material objects which provides both a sense of continuity and markers of temporal change: people find themselves situated in social and historical contexts, where contemporary objects guide practice, and objects from an earlier period either stand out as strange, or evoke a sense of the past.

5. INFORMATION STANDARDS

Extending beyond the concrete material objects referenced via human communication standards, information standards are most often established through the use of images inscribed on/in surfaces of persistent objects. Because these images appear persistent, they support the phenomenon of abstraction: that an image is perceived to "represent" something that is immaterial but persists across time and space. The mechanism through which this occurs is more complex than space allows us to describe fully, but it relies on two basic psychological phenomena and one social process. The first of these entails perceived equivalence between different size scales of visual perception, giving rise to distance perspective [27]. This phenomenon is likely grounded in a

[3] Persistence extending beyond the timeframe of a social encounter and throughout a recurring series of such encounters, is what we are concerned with here.

capacity of human memory that supports the ability to learn invariant arrangements of spatial relations, such as faces, objects, and symbols -- so that people can recognize them without regard to position, size, or view [44]. The second phenomenon entails the affective feeling(s) of collectivity generated during co-present social practices becoming tightly bound to the psychological (internal) images, as "super-added meaning," during performance of recurrent collective practices focused on the images [12][35][38]. The third involves the taken-for-granted character of constitutive social processes: because the social processes are taken for granted, objects that require being socially constituted nevertheless appear as natural objects. Together these phenomena generate emergent effects on the standards such that the features formerly existing as "rules" can be interpreted (understood) as abstract *structures*, and treated as such, even though this substitution is not without problems (as described below in *Section 7*).

For example, persistent objects and inscriptions corresponding to the sequential rules associated with talk-in-interaction, can become transformed into the abstraction of an *ordered list*, in which a syntax (set of rules) specifies that given two items, one *always* precedes the other. Similarly, category membership is no longer thought of simply in terms of rules, but rather as involving nascent structures. The categorization process shifts from heavy dependence upon the recurrent sequencing needed for the ephemeral talk-in-interaction, to the persistent outlines of the object-born images, now understood as abstract structures. With regard to category membership then, *set theory* – which requires no characteristic relationship among the items other than commonality of membership within the set – arises. A more complex structure (with a more complex syntax) can be understood in terms of arbitrary but stable relationships between set members and modeled as a *graph* in which the nodes represent members and the edges represent the relationships. A *hierarchy* then is a structure in which any two nodes in the graph are connected by one and only one path (i.e. there are no cycles).

This "structure" of relationships among items referenced within or by an information standard affords a primary characterization of how different types of information standards can be distinguished from one another, and comprises types such as categorizations, classifications, dictionaries, taxonomies and indexes [32]. In the next sections, we follow Mann & Brooks [32] in identifying two primary forms of information standards: human oriented and machine oriented.

6. HUMAN ORIENTED INFORMATION STANDARDS

Human oriented information standards have many of the same properties as socially-interactional communication standards, though enhanced by the power of abstract representations. For example Brown and Duguid [3] write about the importance of documents in community formation and preservation. Within a social grouping, documents offer a context for negotiating meaning - i.e. discourse practices addressing what the document should "say" function to determine at the same time exactly what the group is about. Importantly though, the concrete objects bearing images associated with abstract human oriented information standards can serve as *media* representing ideas in exchanges between members of social groups that do not co-participate in talk-in-interaction.

As a prime example of this, Yates [57] has researched the evolution of the organizational communication system based on written records, and highlights the importance of printed rules or instructions relative to the practice of standardized procedures. Communication systems were developed incorporating social practices which drew operating information up through different levels of the organizational hierarchy using records and reports, and disseminated policies and procedures via downwards communication. It is not surprising that Walsh and Ungson [54] identify records and files as organizational memory aids much as Radley [36] considered mute objects for individuals.

7. MACHINE ORIENTED INFORMATION STANDARDS

Machine oriented information standards comprise a further variation of human oriented information standards, through the automated processing and replication of representational images across media (concrete objects), effectively bridging communication across time and space. The computational interoperability gained through use of machine oriented information standards is fundamentally necessary for the technological infrastructure of socio-technical systems. These standards are comprised of rigid structures of data representation (semantics), and formal rules for ordering (logical syntax) and for category membership (set theory).

Machine oriented standards (i.e. programming languages and data structures) are often further distinguished and categorized according to other structural differences. For example, binary data and CPU instruction sets, programming languages and formalized semantics of data structures, high-level programming languages. Thus their structure and category membership conform to the constraints of what is called classical category theory. And because their "structures" are even more rigidly constrained than human oriented information standards, they are more likely to engender difficulties with meaning translation [6], and problems in the development of cyberinfrastructure [10][13][26].

Yet precisely because they are subject to these constraints of formal syntax and semantics associated with the persistence of image-bearing objects, these standards do not serve the requirements for ambiguity and indexicality (conduciveness to variable interpretations), and when systems developers attempt to rely upon them to serve needs of human interactional communication, it can therefore lead to problems (e.g. see [43]).

Each such standard is of course subject to a full range of social, political, and economic influences [2]. Some are closed proprietary standards; others are open, promising interoperability among all who abide by the standard. Some standards are highly formalized in their governance and are managed by international organizations such as the Internet Engineering Task Force (IETF), while others have evolved historically and are not formalized by an identified governing body, yet remain pervasive and broadly accepted none-the-less. Yet all machine-oriented standards are structured in terms of syntax and semantics because – at their core – all computers operate in more or less the same way. A stream of binary data is read in by the central processing unit (CPU) and then separated into two categories. Some of the data is treated as data with stable definitions (semantics) that is to be stored and manipulated in some way. Other parts of the input stream are recognized as instructions for manipulating the semantic data according to a formal syntax. Because such documents are interpreted differently from different points of interest however, their boundary object character is not unproblematic.

The necessity to support computationally-automated processing across multiple different platforms often leads to the eruption of

"schema wars" in standards bodies, i.e. when negotiations over technical standards become battlefields between functional, political, and economic fiefdoms. In such cases, the incommensurabilities surfacing in the "differences of opinion" reflect the tensions between the formal logic of computing and the flexible indexicalities intrinsic to social interaction and practices.

8. DISCUSSION

This paper has focused on distinctions between communication and information standards. Our claim has been that the different kinds of communications and information standards within the socio-technical ecosystem can be cataloged according to type of standard, and these are summarized in Table 1.

Table 1. Communication and Information Standards

Actants	Name of Standard	Focal Material Substrate	What is Standard
People and optional shared groupings of objects	Socially Interactive (Human to human) communication standards	Social interaction and the interaction order; optional mute objects	Turn-taking and preference orders and (optional) membership category devices
People and shared groupings of objects ("media"), bearing inscriptions	Human oriented information standards	Social practices and image-bearing objects	Written language, addresses, etc.
Digital technologies and people who work with them	Machine oriented information standards	Digitally-manipulated images displayed on concrete objects, and people	"Abstract structures" ("information")

Ultimately, we assert that developing such a perspective is of utmost importance for design of both social forms and technical information systems, enabling these actants to better interface with each other through the sharing of material artifacts, as two sides of a coin. Our primary point then is that machines constitute and recognize objects differently in social institutions than people do in everyday talk. This has both theoretical and practical implications for both social science and engineering.

8.1 Theoretical implications

8.1.1 Interactive Communication is not Information

The first tenet of our work is that the rules of co-present social interaction – that Goffman terms the interaction order – are different from (and have different consequences than), the institutionalized social structures that depend upon information artifacts and mediated interactions more generally [37].

Our stance is in line with Giddens' assertion [19, p.28] that the mechanisms of system integration (technologically-supported distance communication) necessarily presuppose those of social integration (co-present interaction). While information systems can augment human communications and decision-making, they cannot entirely replace the interpretive and social nature of the sensemaking work performed by humans within the socio-technical eco-system.

This position also echoes the work of Durkheim [11] who argued that what we call "semantic" systems – in which symbols are intended to carry meaning – are closed systems [38][39]. They are "mechanical solidarities" in which persons must be forced to comply. Meaning is possible because everyone is forced to experience the same things and live and think in the same way. In this regard, early computer systems and databases are a lot like early tribal religious and social systems [39][40]: they are closed systems that do not need to, and in fact cannot, communicate with other systems (databases). People who work within a single organization which has its own organizational practices stay within a closed system: every aspect of life in closed tribal circles is invested with meaning, thereby foreclosing the possibility of boundary objects.

When social exchange reaches the point where communication must occur across these groups past a certain minimum density – Durkheim argues that these bounded solidarities break down – and an open form of social exchange based on self-regulating practices develops to fill the void [11]. His examples focus on the bench practices of modern science as indications that objects and technologies alone are not adequate to bridge across differing communities, and that common practices around specific objects are necessary.

8.1.2 Boundary Objects

As boundary objects have been defined, the key to their status is use across many different communities of practice, or stakeholder communities [58]. Star and Griesemer [51] were the first to note that different social groups associated different meanings with the same objects; in their case it was amateur bird watchers and professional biologists both using "the same bird" in different ways. Bowker and Star [2, p. 297] describe boundary objects as plastic enough to satisfy the informational requirements of several communities of practice:

> Boundary objects are those objects that both inhabit several communities of practice and satisfy the informational requirements of each of them. Boundary objects are thus both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain common identity across sites.

And Bowker and Star proceed to argue that this ability to cross domain boundaries makes boundary objects a means of translation across domains [2, p. 297]:

> Such objects have different meaning in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation. The creation and management of boundary objects is a key process in developing and maintaining coherence across intersecting communities.

More to the point, in "Between Chaos and Routine: Boundary Negotiating Artifacts in Collaboration" Charlotte Lee [29, p.309] writes: "Boundary objects are created when groups from different worlds work together. Shared work creates objects which inhabit multiple worlds simultaneously." It is this work of mutually orienting objects through practices that constitutes their character as boundary objects. Our work amplifies the point, maintaining that all recognizable objects require durable shared practices to render them mutually available [18]. Boundary objects, then, are those objects for which the practices that render them mutually

available are durable and cross many social domains of practice. And of course, it is possible that some objects are more easily achieved as boundary objects.

Further in our view, boundary objects do not merely exist – rather they are related to conversational orders (and other sequential orders). Garfinkel [17] refers to objects as "oriented" by participants in interactions. The turn-taking system is one of these boundary crossing systems – enabling people to engage in durable communication across domains in spite of the inherent ambiguities and limitations involved in semantic language forms.

Ethnomethodology further emphasizes that the coherence of boundary objects is not inherent in the objects – but rather, is a result of the sustained work that situated groups of people do to create their coherence: what Lee [29] refers to as "durable cooperation among communities of practice." Without this durable cooperation, even the simplest and most obvious boundary objects would not exist as mutually oriented objects of a particular sort. They are made possible by mutual orientation to practice.

Observation of the interactions within an IS standards-development team suggest the kinds of serious communication difficulties that can develop when a team pushes beyond the boundaries of accepted ideas in a domain of practice [43]. Participants can be mutually committed to a broad community of practice; in this case design work, but, because of small differences in orientation may on any particular occasion not be mutually oriented toward a developing order of practice. Mutual commitment to a "community" in the conventional sense (ideas, beliefs, theories) is not what is required – in fact it can create boundaries. Rather, mutual orientation to a developing "order" of practice; what Durkheim referred to as a self-regulating practice [11], is required. Sensemaking in such creative domains requires the ability to recognize and confirm the recognition of turns at talk – to create meanings that can cross boundaries. It is in this way that the competent practice of ordinary turntaking allows participants to communicate across domain boundaries in communication with a situated group of practitioners.

Bowker & Star [2, p.297] also suggest that boundary objects may be abstract or concrete, arguing that abstract constructs can function as boundary objects. But ethnomethodology would stress the oriented status of visible objects, and would add that even this latter way of formulating boundary objects may treat objects too independently from their contexts.

We close this section by noting that while we recognize the importance of standards intentionally designed to bridge human/machine standards, such as ontologies, data schemas, and classified (bibliographic) identifiers, we again stress the fundamental primacy of the distinct class of human oriented standards, which can support the ambiguity and ad hoc exceptions essential for social communication.

8.1.3 Socio-Technical Systems

As the differences between socially interactive communication standards, human oriented information standards, and machine oriented information standards becomes clearer, issues of agency and materiality in socio-technical systems may be more readily addressed.

8.2 Practical implications

There are practical implications of the results as well. First, we believe that our distinctions across types of standards should be helpful for designers of socio-technical systems, especially as they are involved in the authorship of standards. Clarifying the distinction between communication, human oriented information and machine oriented information standards and drawing attention to the issues of ambiguity and competing interpretation associated with communication and human-oriented information standards, should increase technology developers' awareness of correlations between different communities of practice and their information standards, as well as organizational designers' appreciation for aspects of social interaction that are inherently not automatable.

There are corollary implications for developments in cyberinfrastructure, regarding distinctions between the interpretive flexibility needed for knowledge creation, and the enforcement of institutionalized standards across communities of practice. Similarly, with regard to e-Science, these distinctions may help clarify some of the trade-offs between data-rich and data-impoverished scientific fields [47].

9. CONCLUSION

9.1 Limitations

A major limitation of this work is that it is illustrated with only a small number of examples. Empirical studies compiling a broader and more robust catalog of types of communication and information standards is needed to confirm the accuracy and comprehensiveness of this typology. Secondly, field research to identify patterns of usage against these types, inventorying modalities of standards usage, would be very helpful toward allowing creators of such standards to design and select more useful standards.

9.2 Future Directions

We would like to see aspects of this work developed in further support of organizational design. Minimally, there is a need for empirical work to document patterns of social interaction, organizational routines and institutional contexts surrounding the use of each type of human-oriented information standard. Once completed, this work could be used to inform organizational design choices and strategies. Ultimately, knowledge of both human-oriented and machine-oriented types of information standards should be strengthened and deepened, to support more robust integration of human/social and technological subsystems.

Ultimately, we would also like to see the types of human communication, and human oriented information standards that we have identified here become associated with a set of identifiably-recurring communication and analysis problem sets (including operations such as addressing, confirming identity, searching and browsing). This work might then support the development of design patterns [1][14] for information standards, where a design pattern is comprised of design types plus use case scenarios. These design patterns could then be used to support various types of hybrid socio-technical analysis within enterprises.

And perhaps not surprisingly, we also harbor hopes that this work may eventually help clarify some of the asymmetric agency issues intrinsic to actor-network theory, as well as contribute to knowledge about improving processes of technological innovation.

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