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# Generating an Ontology from Scientific Works: Initial Results

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## Abstract

*Attempts to produce adequate and long-lived subject indexes of information systems and computer science research have failed. In this paper we report preliminary results of an approach by which the terms expressed in research literature, such as that in information systems, can be systematically and meaningfully categorised. The approach is based on Roman Ingarden's ontological theory of the written scholarly work: its nature, existence, and categorisation, and builds on Grounded Theory: a rigorous grounded qualitative research method addressing how meaningful categories can be analysed from text and related to each other. We have found that the key guiding unit of analysis operationalising Ingarden's approach through Grounded Theory is the "reported research activity" and that the process is possible although labour intensive. On the basis of using the approach, we propose simple steps to improve the quality of keywords in reported research.*

**Keywords**

ACMCCS: H.3.1 [Information Storage and Retrieval]: Content Analysis and Indexing – Thesauruses General Terms: Standardization, Theory

## INTRODUCTION

Categorisation schemes are widely used as a way of understanding and structuring activities in particular domains. Even the decision to not categorise is an implicit categorial decision: "things I categorise" vs "things I don't categorise." The motivation for this research was to develop a categorisation scheme for the IS research domain to be used with a database. While the target database does not contain documents, the documents in journals publishing IS research is an obvious source to provide data for the creation of such a categorial scheme.

Of the currently published journals with instructions to authors accessible from the *Index of Information Systems Journals* (Lamp, 2004), most either don't mention keywords, or give vague instructions ("don't use plurals", "don't use overly commonplace terms", "use American spellings"). Eleven journals have their own schemes, which vary in complexity. Three journals use categorisation schemes devised by other authorities, reflecting their multidisciplinary nature (Lamp & Milton, 2003).

Twenty, mainly published by the Association for Computing Machinery (ACM) or the IEEE Computer Society (IEEE-CS), use the ACM Computing Classification System (CCS) (ACM 1998a) or an extended version of it devised by the IEEE-CS. The ACM Classification Update Committee maintains the CCS. The issue of the long-term applicability of categories has posed significant problems for the Classification Update Committee. In 1998 they considered a major restructure of the scheme, but decided against it. The issue of a major redesign of the CCS remains on their agenda. The 1998 version is flagged on the ACM website as "Valid in 2006".

*MISQ* had a Keyword Classification Scheme, first proposed in 1988 (Barki et al, 1988), revised once in 1993 (Barki et al, 1993) then abandoned in 2003 (Weber 2003). Unlike the CCS, it had top-level categories covering issues outside the domain of information systems such as "Reference Disciplines" and the "External Environment", to cater for the multidisciplinary and diverse nature of the domain. A major motivating factor in MISQ's decision was the growing prevalence of full text search facilities (Weber, 2003).

The *MISQ* keyword scheme maintainers rightly stated that "[a]s experience with the [CCS] scheme has shown, revision and maintenance are of utmost importance if the scheme is to remain useful and usable." (Barki et al, 1988, p300) and appeal to Foskett (1977) in supporting the need for regular renovation of schemes: "those schemes which have relied on the genius of their compilers without the backing of an adequate organization, have gradually fallen into obsolescence, whereas those schemes which have adequate backing continue to progress" (p196).

While the above examples have been drawn from the domain of academic journals, the use of indexes is not restricted to such domains. The prevalence of free text searching has been a motivator for the abandonment of indexes by journals (eg Weber, 2003). However, there are many applications which do not have an underlying body of text on which free text searching can be carried out, and yet access by some form of surrogate, commonly a subject index, is required. As stated above motivation for this research was just such a database.

Recently Grudin (2006) stated that

> "the creation of metadata requires that the creators of objects, or people working on their behalf, put in the effort to add metadata for the potential benefit of others who generally remain unseen and may in fact never materialize. Object creators often have little incentive to generate metadata. … This problem can be partially addressed by devising an overarching classification system. Such systems require considerable effort to create and maintain."

A significant contributing factor to the amount of effort required is that no recognised rigorous method for generating schemes appears to exist. Certainly none could be discovered in the literature.

In this paper we present initial work on categorisation scheme development based on the philosophy of Roman Ingarden and the rigorous qualitative research approach called Grounded Theory. Ingarden developed a number of frameworks for ontological analysis of texts, which are documented in his books *The literary work of art* (1965) and *The cognition of the literary work of art* (1968). While Ingarden's primary focus was on mainstream literature, he also considered scientific works as a borderline case of the literary work of art. We are involved in a project, a significant aspect of which involves the analysis of papers reporting information systems research in academic journals and for which preliminary results are reported here. A broader description of this project and a discussion of the rationale for using Ingarden's frameworks and Grounded Theory coding techniques can be found in Lamp & Milton (2003, 2004 and 2007).

The paper proceeds as follows. We present a method whereby scientific works can be analysed to generate terms for a categorial scheme. We then present results of analysing one volume of an 'A+' grade information systems journal (ACPHIS, 2008), *Information Systems Research*. We then discuss the results drawing conclusions about the process and identifying further steps required transform these terms into a categorial scheme. At this stage of our work, the focus is to determine whether this approach will work at all, rather than to evaluate the feasibility of using this approach in terms of the results delivered for the effort expended.

## METHOD

The method used and reported on in this paper appropriated the coding techniques from Grounded Theory method (Glaser & Strauss, 1967). Grounded Theory method diverged into two camps during the 1990s, one approach based on developing abstract conceptualisations using an emergent coding family, and the other focusing on full description using a predetermined coding family. As previously reported (Lamp & Milton, 2007), our method seeks to develop abstract conceptualisations, but the nature of the coding family is, to an extent, predetermined and, hence, does not fit precisely into either camp. We appropriate the techniques used in the Grounded Theory method as a foundation for developing a rigorous approach to the ontological analysis of scientific works. Grounded Theory method was selected as it shares a consistent philosophical perspective with Ingarden's ontological analysis. To give a comprehensive description of Grounded Theory method is well beyond the scope of this paper. The following paragraphs describe our adoption of this method and our rationale for our mode of its application.

Grounded Theory method can be considered to consist of two phases; substantive coding and theoretical coding. Substantive coding itself consists of two sub-phases: open coding and selective coding.

In open coding the analyst aims to "generate an emergent set of categories and their properties which fit, work and are relevant for integrating into a theory" (Glaser, 1978: 56). Units of meaning are examined and coded against as many categories as may fit. New categories emerge, and new units of meaning fit existing categories.

The Grounded Theory method researcher is looking for Basic Social Processes (BSPs). In undertaking open coding the Grounded Theory method researcher considers three questions (Glaser, 1978: 57):

- What is this data a study of?
- What category or property of a category, of what part of the emerging theory, does this incident relate?
- What is actually happening in the data?

In considering scientific works, we define the equivalent concept to be the Reported Research Activity (RRA). An RRA is central to the understanding of the contribution of a scientific work, as a BSP is to understanding a

human activity. The changed terminology emphasises that our approach appropriates the Grounded Theory coding approach. To paraphrase Glaser's three points above:

- What is this scientific work reporting research on?
- What category or property of a category, of what part of the emerging theory, does this research activity relate?
- What is actually being undertaken in the research?

Selective coding occurs when the analyst identifies core categories and limits his coding to "those variables that relate to the core variable in sufficiently significant ways to be used in a parsimonious theory" (Glaser, 1978: 61). In the context of this research program this corresponds to creating a parsimonious categorial tree where more specific terms are subsumed in more general categories. The researcher moves from open coding to selective coding when theoretical saturation is achieved. Theoretical saturation is said to be achieved when consideration of further data is not contributing further categories. Selective coding would be inappropriate for a study of only one year of one journal, where the aim is to generate a categorisation for the IS domain, as it is highly unlikely that theoretical saturation would be achieved.

Theoretical codes conceptualize how the substantive codes may relate to each other as hypotheses to be integrated into a theory (Glaser, 1978: 73). Theoretical coding is beyond the scope of this paper.

A full description of Ingarden's ontology as it applies to scientific works can be found in Lamp & Milton (2007). In outline, scientific works are asserted by Ingarden (1968: 147) to consist almost exclusively of genuine judgements, the most significant ontic items of which are:

- the states of affairs described;
- schematized aspects; and
- the represented objectivities.

Ingarden states that genuine judgements are assertions that may be true or false, but they lay claim to truthfulness; eg a scientific work may report "The management style of company A was undemocratic" which is a result perceived as true by that researcher, and yet a second researcher may report a different result. Despite their essential contradiction, both statements are genuine judgements on a state of affairs.

Objects represented in a literary work are derived purely intentional objects projected by units of meaning (Ingarden, 1965: 218). They are intentional because an author has written them with a purpose. For scientific works it is the transmission of cognitive results (Ingarden, 1965: 330). They are derived, because we cannot enter the mind of the author. Finally, they are projected, because it is only through language (in this case written language) can we understand what is intended.

As a reader reads a passage of words and phrases (meaning units) containing a represented object, he or she relates directly to the states of affairs that the represented object is helping to clarify. Consequently, a particular represented object within a scientific work causes us to direct ourselves to corresponding states of affairs. Because we are dealing with a scientific work rather than a literary work of art, this directional ray passes through the content of these represented objectivities so that they refer to objectively existing states of affairs, or to objects contained within them rather than to some fictional creation (Ingarden, 1965: 329). This is shown in Figure 1, but it should be noted that this is a dramatic simplification of a complex thought process which may involve multiple represented objects and states of affairs, rather than a simplistic mapping.


Figure 1: The directional meaning ray

Literary works necessarily consist of incomplete descriptions, termed schematized aspects, which contain fulfilled (explicitly described) components and unfulfilled components, which while not explicitly described, may not be indeterminate. Consider a scientific work describing an organisation's use of networked computers. The scientific work may describe the network in a general sense, it may explicitly describe some aspects of it, understanding of which is essential to understanding the state of affairs being reported, but will not give details on every aspect. The reader may fill these out from schematized aspects held in readiness from previous experiences. Prompting the most appropriate schematized aspect is influenced by the word choice and represented objectivities selected by the author. The more a represented objectivity is accepted in a discipline the greater reliance an author will place on schematized aspects being held in readiness. While two readers may, because of differing academic backgrounds and experience, associate the same meaning unit with different schematized aspects, the more the reported states of affairs and represented objectivities are accepted in a discipline, the less likely there will be a significant variation. It is also worth noting that, over a period of time, a new reading may trigger different schematized aspects, as the understanding of the discipline evolves.

Ingarden's categories form the basis of a coding family grounded in his ontology of the scientific work. Further categories may be added, dealing with matters relating to publication and journals, other than the content of the papers themselves (time to publication, reviewing status, intellectual property status), which were suggested in Lamp (2002), or which may emerge as valuable during the process.

The Grounded Theory coding technique united with Ingarden's ontological analysis would appear to meet our needs, but we do not claim that what we are undertaking is Grounded Theory method as it is not in accord with either the Glaserian or Straussian approaches. We appropriate the coding technique from Grounded Theory method and adapt it to ontological analysis of text.

This paper concerns itself with the open coding of the journal *ISR* for 2005. This journal was the first of a number of journals analysed in this project and this paper reports on the initial results of its analysis.

## RESULTS

In 2005, *ISR* published volume 16, consisting of four issues containing a total of twenty-five articles. Four of the articles were Editorials, and the balance of the articles reported research activities. The journal *ISR* is one of the few journals which provides some guidance on keywords. The guidance is limited to a list of keywords (*ISR* 2007; see Table 1), without any instructions on the status of these keywords, how many are to be used in an article or what to do if they are inappropriate.

Table 1. Keywords prescribed by *ISR*

| | |
|---|---|
| Analytical modeling | Inter-organizational information systems |
| Business value of IT | Interpretive research |
| Case studies | IS leadership |
| Citation analysis | IT and new organizational forms |
| Competitive impacts of IS | IT diffusion and adoption |
| Computer-mediated communication and collaboration | IT impacts on industry and market structure |
| | IT-enabled supply chains |
| Critical perspectives on IT | Knowledge management |
| Data communications | Laboratory experiments |
| Decision support systems | Longitudinal research |
| Design and evaluation of IT infrastructure | Management of IS projects |
| Econometrics | Management of IT human resources |
| Economics of IS | Mobile computing |
| E-learning | Network analysis |
| Electronic commerce | Network economics |
| Electronic financial markets | Outsourcing |
| Electronic markets and auctions | Questionnaire surveys |
| Enterprise systems | Software development methodologies |
| Ethnographic research | Strategic management of IT |
| Event studies | Systems design and implementation |
| Field experiments | User acceptance of IT |
| Information Systems and Organizational Change | Virtual teams |
| Institutional aspects of Information Systems | Workflow and process management |

In 2005, a total of 109 keywords were used by articles published in *ISR*. For reasons of size, this list is not included but is accessible at http://<removed for reviewing>/docs/isr2005actual.pdf. Of these 109 keywords,

only nine appear in the list of *ISR* prescribed keywords (see Table 2). This is a disappointing result, though perhaps hardly surprising given the lack of instruction. The number of keywords used in an article ranged from a minimum of three to a maximum of ten, with a median of five. Only two keywords, *e-commerce* and *virtual teams* were used more than once. These keywords were used twice. Of these two keywords, only *virtual teams* was a keyword prescribed by *ISR*.

Table 2. Prescribed Keywords Used in *ISR* articles, 2005

| Prescribed keywords | Articles |
|---|---|
| critical perspectives on IT | 1 |
| ethnographic research | 1 |
| interpretive research | 1 |
| knowledge management | 1 |
| management of IS projects | 1 |
| outsourcing | 1 |
| system design and implementation | 1 |
| virtual teams | 2 |
| workflow and process management | 1 |

**Applying the method**

The following description of applying the method uses passages from an article in volume 16, Majchrzak et al (2005) to illustrate the method. Nvivo was used as a tool to track the coding and documents. The authors of that article chose the keywords "knowledge management, collaboration, virtual teams, distributed teams, knowledge sharing, group support systems" to describe the article.

When applying our method, specific attention was paid to passages containing phrases such as "we derive," "we specifically focus on," "we include" and "we do not try to" to identify RRAs. Statements with phrases like these often characterise the represented objectivities or states of affairs contained in the RRAs being studied. Consider the following paragraph:

> "We derive a theoretical model from Te'eni's (2001) cognitive-affective model of communication to elaborate how information technology (IT) can support an individual's communication of context to develop collaboration know-how."

The paragraph was coded as using the represented objectivity "model building" concerning the states of affairs "collaboration," "communication," "know how" and "IT support". The represented objectivity, the process of model building understood by researchers, is providing information on how the authors approached their investigation of the states of affairs, collaboration, communication, use of know how, and levels of IT support found in the organisations under study.

Similarly, the passage:

> "In sum, we argue that the opportunities for misunderstanding when performing nonroutine tasks are so great that collaboration know-how development will benefit from any IT support for contextualization even if the support is partial. When individuals perform routine tasks, however, partial IT support will lead to reduced collaboration know-how development because individuals not only must perform the task, but must also expend cognitive resources at the same time to resolve and reconcile the implications of the missing context."

was coded as a represented objectivity "a priori hypotheses," as it was asserting a view held by the authors before their investigation took place, therefore describing the way they viewed their investigation.

Following this method, the ontic items in Table 3 were identified.

Table 3. Ontic items identified in Majchrzak et al (2005)

| Represented objectivities | States of affairs |
|---|---|
| A priori hypotheses | Collaboration |
| Contextualization | Communication |
| Interviewing | Descriptive results |
| Model building | Implications for practice |
| Multi-country | IT support |
| Quantitative analysis | Know how |
| Survey | Theory building |
| Task-technology theory | Virtual teams |

In Table 3, "model building" is coded as a represented objectivity, and "theory building" is coded as a "state of affairs". Model building was coded from the first passage quoted above: "We derive a theoretical model." This phrase describes how the researchers intend to present their findings. They are not discussing building models as an activity in itself, but as a way of presenting or viewing their research. As such this is not a state of affairs, but a represented objectivity. In contrast, theory building was coded on the basis of the two following passages:

> "Our study represents an initial attempt at empirically demonstrating the value of ideas developed by Boland et al. (1994) and Hedberg and Jonsson (1978) that IT systems and work practices that support the exchange of contextual information are related to knowledge development. These researchers incorporated contextualization support within a broader concept of support for an active inquiry and sense-making process."

> "This suggests that, in contrast to both the task-technology theories and virtual team literature that argue for the importance of face-to-face contact (e.g., Bhappu et al. 2001, Cramton 2001, Hinds and Bailey 2003, Mannix et al. 2002, Maznevski and Chudoba 2000), face-to-face contact is not required for nonroutine tasks when IT provides contextualization support. Second, the dip in collaboration know-how development found with routine tasks when IT support for contextualization was partial suggests that it may not be the richness of the media that contributes to collaboration know-how development, but rather the level of support for contextualization that the media provides."

These passages describe how the research contribution reported in the article is building theory in this area of research. It is not describing theory building as an approach, it is actually building theory. Those passages are reporting genuine judgements regarding a state of affairs and are coded accordingly. It should be recalled that the choice of codes is influenced by the author's word choice and coder's schematized aspects held in readiness.

These examples clearly illustrate the value of distinguishing between represented objectivities and states of affairs as search terms. A researcher interested in papers exploring the concept of model building as an end in itself would be looking for model building as a state of affairs, and would not retrieve this paper. Similarly a search with "theory building" and the name of theory a researcher might be interested in as states of affairs would not return papers applying that theory, but would return this paper.

Table 4. Represented objectivities in *ISR* volume 16

| Term | Documents |
|---|---|
| a priori hypotheses | 16 |
| analytical framework | 1 |
| attitude theories | 1 |
| conceptual framework | 1 |
| configuration theory | 1 |
| consumer-piracy behaviour model | 1 |
| Contextualization | 1 |
| contract-theoretic framework | 1 |
| Cost | 4 |
| design science | 1 |
| developing country | 1 |
| diversity of participants | 1 |
| Econometrics | 1 |
| economic analysis | 3 |
| elaboration likelihood model | 1 |
| Ethnography | 1 |
| Experimentation | 6 |
| field study | 5 |
| game theory | 3 |
| grounded theory | 1 |
| habit-automaticity perspective | 1 |
| Induction | 1 |
| instant activation perspective | 1 |
| interviewing | 2 |
| methodology development | 1 |
| model building | 12 |
| multi-country | 2 |
| observation | 1 |
| ontology | 1 |
| optimal control theory | 1 |
| perceptions | 1 |
| practice-theoretical approach | 1 |
| psychological contract violation | 1 |
| qualitative data collection | 1 |
| quantitative analysis | 20 |
| reflection-in-action | 1 |
| resource based theory | 1 |
| set-theoretical notation | 1 |
| social impact theory | 1 |
| structural equation modeling | 1 |
| survey | 7 |
| task-technology theory | 1 |
| technology acceptance | 1 |
| technology-organisation-environment | 1 |
| trust | 1 |

The analysis of Majchrzak et al (2005) identified a larger set of terms than those chosen by the authors. The following author assigned keywords were not identified by our method: knowledge management, distributed teams, knowledge sharing, group support systems. "Knowledge management" is an *ISR* prescribed keyword but only appears once in the body of the article as "knowledge management systems," as a type of system which the conclusions in the paper could be extended to cover. "Distributed teams" is used as a synonym for "virtual teams." It is not an *ISR* prescribed keyword, while "virtual teams" is a prescribed keyword. "Knowledge sharing" appears when discussing a form of survey instrument and when mentioning types of IT support

applications. "Group support systems" does not appear in the body of the article. Neither "knowledge sharing" nor "group support systems" are *ISR* prescribed keywords.

Applying the method to the other twenty articles produced the represented objectivities and states of affairs in Tables 4 and 5 respectively.

Table 5. States of Affairs in *ISR* volume 16

| Term | Documents |
|---|---|
| accounting firms | 1 |
| accounting information systems | 1 |
| Algorithms | 2 |
| automatic use | 1 |
| b2b ecommerce | 1 |
| buyer-seller relationships | 1 |
| collaboration | 3 |
| communication | 1 |
| consumers | 1 |
| control | 1 |
| data mining | 1 |
| data structures | 1 |
| descriptive results | 9 |
| e-business | 5 |
| expert systems | 1 |
| groups and teams | 1 |
| human resource practices | 1 |
| implications for practice | 11 |
| information processing | 1 |
| information quality | 3 |
| information sharing | 1 |
| IT support | 1 |
| know how | 1 |
| market segmentation | 1 |
| online auctions | 3 |
| online brokerage | 1 |
| power | 1 |
| pricing strategies | 2 |
| privacy | 1 |
| project management | 1 |
| quantitative results | 15 |
| reputation mechanisms | 1 |
| security | 3 |
| social loafing | 1 |
| software engineering | 1 |
| system development | 1 |
| system quality | 1 |
| theory building | 4 |
| user satisfaction | 3 |
| users | 5 |
| virtual teams | 1 |
| web personalisation | 1 |
| website promotion | 1 |

## DISCUSSION

One issue which emerges starkly from this analysis is the tiny degree of adherence to keyword schemes prescribed by that minority of journals which demand them. Nine out of 109 keywords actually used were in the *ISR* list of keywords. If this degree of adherence is a norm within a journal, it means a researcher attempting to search an archive of articles using prescribed keywords, would have an extremely low recall score and one would have to question the usefulness of such an archive. Of the 109 author chosen keywords, only two keywords were used more than once. Again, the recall score of a search under such a regime would be very low. Neither of the two available approaches is effective.

As has been noted previously, only two author chosen keywords were used in more than one article. The method described in this paper identified forty-five represented objectivities and forty-three states of affairs, a total of eighty-eight terms. Eleven represented objectivities and thirteen states of affairs were used in more than one article.

Fourteen author chosen keywords were also coded as states of affairs. Eight author chosen keywords were also coded as represented objectivities. In some cases the keywords were equivalent rather than identical, because there were minor variations. For example "web personalisation" was our term, but "web personalization" was used by the authors. Failing to cater for regional spelling variations is another well known issue with author assigned keywords. We assigned "technology acceptance" as a term, but the authors assigned "technology acceptance model." For the most part, terms emerging from the analysis method tended to be more general than those chosen by authors.

It is also worth noting that, examining the terms we have identified, the ones recurring the most, concern the research process or artefacts (eg. quantitative results and quantitative analysis). This is not surprising but worth noting as a dimension most often overlooked – that of the research method, tools, techniques etc.

It could be argued that these results are already more useful as categories as they appear in multiple articles, have a degree of overlap with author assigned keywords, but extend beyond them and therefore will be more useful as search terms. However, it should not be assumed that repeated use is always a virtue. For example, one term, "quantitative analysis," is coded against all but one article. As a search term it would be of very limited use in distinguishing between articles in this volume of *ISR*.

In order for a categorial system to provide a high degree of recall (Foskett, 1977), the level of generalisation or specialisation must be appropriate to the domain that is categorised. This process takes place during selective and theoretical coding. As has been previously noted, to move on to this phase requires that the investigation reach theoretical saturation. For that to happen coding of further journals must take place.

We do not suggest that this investigation is even close to theoretical saturation. As we approach this some of the issues unresolved in this paper may well be addressed. For example, "knowledge management" has not emerged as a category using our method, yet the authors of one of the papers hold the paper to be about knowledge management. The term we chose from that paper was "knowledge management support." It may be that, after further journals are examined, that it will be decided at, say, the theoretical coding stage, that "knowledge management" is a more useful term.

## CONCLUSIONS

An ontology is a complete categorisation of a domain. It also contains significant and useful relationships between the categories. The keywords and terms discussed in this paper are only one dimension of developing an ontology.

Keywords in a paper seek to say "if people use these words, they will describe the essence of the knowledge contributed by what is reported in this RRA" - what it is about, what it relates to, what it finds, why it is important. Thus keywords must name those part(s) of the discipline to which the RRA contributes and the research perspective from which the study was undertaken – the states of affairs and represented objectivities.

A promising set of initial terms has been extracted from volume 16 of *Information Systems Research*. The initial terms have some overlap with author chosen keywords, but expand on those in useful directions. At this early stage of the project, it is not possible to be more specific than that.

The next phase of the project is to expand the data collection. The full data collection will cover the 2005 issues of *MISQ*, *Information and Management*, *J. of Management Information Systems* and *Information Systems Research*. These journals have been chosen as senior respected information systems journals.

In the course of this analysis, it is expected that theoretical saturation will be achieved, and analysis will progress through selective and theoretical coding to produce a useful set of categories and values. This experience will also provide information on the amount of time and effort required, and hence comment on the feasibility of the approach.

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