

EPC Exhibit 138-28.2
May 15, 2015

THE LIBRARY OF CONGRESS

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To: Jonathan Furner, Chair
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From: Rebecca Green, Assistant Editor
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OCLC Online Computer Library Center, Inc.

Via: Michael Panzer, Editor in Chief
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Re: Relational aspects of subject authority control: The contributions of classificatory structure

Attached is a paper to be presented at the International UDC Seminar 2015 on the expression of relationships in a classification system, using the DDC as a case study, from the perspective of subject authority control. The theme of the seminar is “Classification and Authority Control: Expanding Resource Discovery,” and will be held 29-30 October 2015 in Lisbon.

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Relational aspects of subject authority control: the contributions of classificatory structure¹

Abstract: The structure of a classification system contributes in a variety of ways to representing semantic relationships between its topics in the context of subject authority control. We explore this claim using the Dewey Decimal Classification (DDC) system as a case study. The DDC links its classes into a notational hierarchy, supplemented by a network of relationships between topics, expressed in class descriptions and in the Relative Index (RI). Topics/subjects are expressed both by the natural language text of the caption and notes (including Manual notes) in a class description and by the controlled vocabulary of the RI's alphabetic index, which shows where topics are treated in the classificatory structure. The expression of relationships between topics depends on paradigmatic and syntagmatic relationships between natural language terms in captions, notes, and RI terms; on the meaning of specific note types; and on references recorded between RI terms. The specific means used in the DDC for capturing hierarchical (including disciplinary), equivalence, associative relationships are surveyed.

Keywords: Dewey Decimal Classification; DDC; relationships in subject authority control; classification system structure

1. Subject authority control and classification schemes

“The purpose of authority control is to ensure consistency in representing a value—a name of a person, a place name, or a term or code representing a subject—in the elements used as access points in information retrieval. . . . In addition to ensuring consistency in subject representation, a subject authority system may also record established semantic relationships among subject concepts and/or their labels” (FRSAD, 2011: 8).

The FRSAD (2011) model sets forth three groups of entities as potential bibliographic subjects. Group 1 entities—work, expression, manifestation, item—are the intellectual or artistic products described by bibliographic records. Group 2 entities—person, corporate body, family—are responsible for the content, production, dissemination or custodianship of Group 1 entities. Group 3 includes all other subject entities: concept, object, event and place. From the perspective of subject authority control, entities in Groups 1 and 2 rely on the same fundamentals that govern (non-subject-oriented) authority control over them. Authority control over two of the Group 3 entities—events and places—are addressed in part in authority control over corporate bodies. This leaves authority control over concepts and objects within the unique scope of subject authority control.

In this paper we explore the contributions of classificatory structure to semantic relationships in the context of subject authority control, using the Dewey Decimal Classification (DDC) system as a case study. We focus our attention

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on subject authority control over Group 3 entities, which we collectively refer to as *topics*, especially concepts and objects.

Discussions of subject authority control typically focus on thesauri, featuring atomic concepts and their corresponding post-coordinate terms. But classification systems differ from thesauri in significant ways; these differences have profound effects on the semantic relationships operative in the system. The most significant difference is that the central unit of a classification is a class, designated by a notation or code, rather than a concept, designated by a term. (Alternatively, a class may be designated by its hierarchically-contextualised caption.) By definition, a class is a set. Alternatively, we may say that the essential nature of classes is to group (presumably like) things together. From an extensional perspective, the members of the classes in a bibliographic classification system are the bibliographic resources assigned to them. But from an intensional perspective (which is our perspective here), the members of the classes in a bibliographic classification system are topics.

The classes of the DDC have been described as “topic neighborhoods” (Green & Panzer, 2010) or “conceptual [spaces] in which topics are located” (Green et al., 2013). The classificatory structure of the DDC links its classes into a notational hierarchy, supplemented by a network of relationships between topics, expressed in class descriptions and in the Relative Index (RI). That is, topics are expressed both by the (semi-)natural language text of the caption and notes (including Manual notes) given for a class and by the controlled vocabulary of the alphabetic index that shows where topics are treated in the classificatory structure. (Even though the topics in bibliographic classification systems are often complex [pre-coordinate] concepts, thesaurus-like features are not absent from them.) The expression of relationships between topics depends on paradigmatic and syntagmatic relationships between natural language terms in captions, notes, and RI terms; on the meaning of specific note types; and on references recorded between RI terms. The interrelationships among the components of the DDC are shown in Figure 1.

2. DDC classificatory structure and paradigmatic relationships

While classification systems differ from thesauri in significant ways, the two types of knowledge organization systems also have major similarities, especially with respect to the types of semantic relationships they convey. Indeed, we find the same paradigmatic relationships in both: hierarchical relationships, equivalence relationships, and associative relationships.

These semantic relationships hold between topics. Due to their conceptual nature, we often refer to topics symbolically, using words as our default symbol system. As a result, lexical relationships commonly parallel the semantic relationships of interest to us. In the discussion below, we take advantage of this parallelism between semantic and lexical relationships, avoiding the risk of being overly pedantic by not being too careful to distinguish between them. But

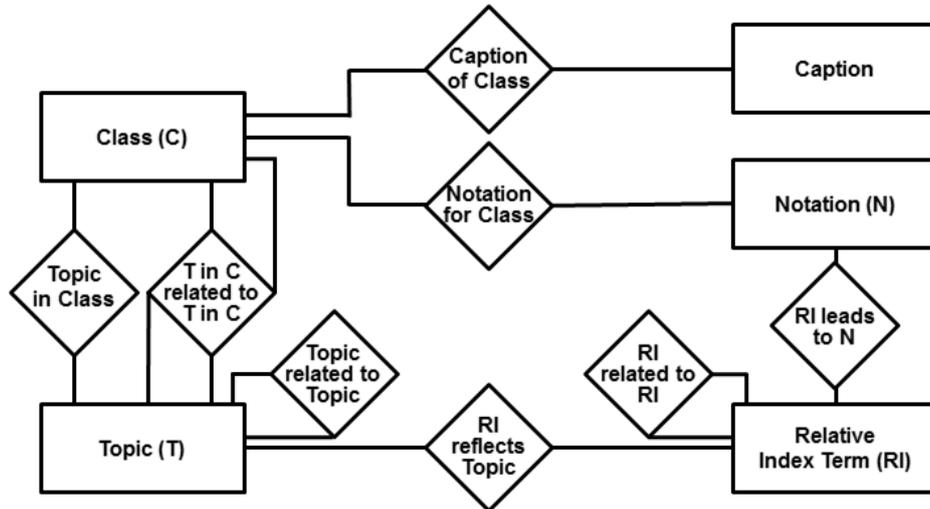


Figure 1: *Topic-oriented data model of DDC*

where it matters, we will refer to topic X and use quotation marks around lexical items.

2.1 DDC classificatory structure and hierarchical relationships

Hierarchical relationships are expressed in the DDC through its structural hierarchy, which consists of both its notational hierarchy (where the decimal notation is expressive in that the relative specificity of hierarchically-related classes tends to correlate with the length of their corresponding notations) and the additional relationships defined through see references. A study of the relationships underlying the DDC notational hierarchy (Green & Panzer, 2011) identified specialization (FRSAD's generic relationship), instantiation (FRSAD's instance relationship), and whole-part relationships. For example, the relationship between 005.75 Specific types of data files and databases and 005.758 Distributed data files and databases is one of specialization: all distributed-data-files-and-databases are specific-data-files-and-databases, but only some specific-data-files-and-databases are distributed-data-files-and-databases. The relationship between 224 Prophetic books of Old Testament and 224.8 Amos is one of instantiation, the book of Amos being a named instance of the class of prophetic books of the Old Testament. Various whole-part relationships are also found: T2—57 Siberia (Asiatic Russia) is a portion of T2—5 Asia; within public administration, 352.4 Financial administration and budgets has as one of its components 352.46 Public expenditures; and 340.55 Medieval European law is an element of the 340.55-340.59 Medieval, modern, religious systems of law collection. While the notational hierarchy ostensibly identifies relationships between classes, the ability to differentiate between types of hierarchical relationships relies wholly on the topical character of the classes.

The DDC's notational hierarchy defines a monohierarchical tree structure. Its structural hierarchy accommodates polyhierarchy through see references. The DDC's see references ostensibly lead from one class (the source class) to another class (the target class) by virtue of a topic in the target class; the fuller picture is that a see reference is dependent on topics in both source and target classes. Consider, for example, the following class description, which contains three see references:

170 Ethics (Moral philosophy)

Class here conscience, good and evil; ethics of specific subjects, interdisciplinary works on social ethics

For religious ethics, see 205; for social ethics as a method of social control, see 303.372. For ethics of a specific religion, see the religion, e.g., Christian ethics 241

This class is the interdisciplinary number for ethics (a statement confirmed by the Relative Index entry for Ethics, with no subheading, which points to this class), and the ethics of several specific subjects (e.g., political ethics, medical ethics, legal ethics) are set out in its subdivisions. We would therefore expect to find religious ethics here as well. But the first see reference tells us that works on this particular specialization of ethics / on the ethics of this specific subject are to be classed elsewhere, in 205 Religious ethics. (The third see reference tells us, however, that ethics of specific religions are not classed in 205 Religious ethics, but in classes specific to each religion.) On the basis of the first see reference, the topic religious ethics is hierarchically subordinate to both 170 Ethics and 201–209 Specific aspects of religion. Although the topics are interrelated, it is not the presence of “conscience” or of “good and evil” in the class-here note at 170 that motivates this see reference; it is the presence of “ethics of specific subjects”. Thus, while only the topic in the target class is named in a see reference, the topic in the source class (although often named in the class description) must be inferred. In the case of scatter see references, of which the third see reference is an example, the see reference leads to a set of target classes; the topic in each target class must be instantiated separately. Thus, “ethics of a specific religion” refers in turn to Christian ethics, Buddhist ethics, Hindu ethics, Jewish ethics, Islamic ethics, and so forth.

2.2. DDC classificatory structure and equivalence relationships

FRSAD (2011) treats the equivalence relationship only as a lexical relationship between words and not as a semantic relationship between topics. That is, FRSAD may be said to posit the unity of any given topic (FRSAD's *thema*), to which multiple lexical items (FRSAD's *nomens*), within a single language or across multiple languages, may refer. An equivalence relationship holds between the various lexical items that refer to the same topic.

Is it possible for two topics to be equivalent? In some contexts it has been argued that two concepts are equivalent if their extension is the same, that is, if they apply to the same set of items. But we really are more concerned with equivalent intension/meaning. We resolve the quandary only pragmatically by positing semantic relationships among the topics in class descriptions and restricting lexical relationships to the Relative Index.

Equivalence relationships have several modes of expression in the DDC (Mitchell, 2001), including caption qualifiers, variant name notes, and former name notes. Consider, for example, the following class descriptions:

- | | |
|------------|---|
| 612.115 | Coagulation (Clotting) |
| | Including role of fibrin, fibrinoplastin, plasma, thrombin in clotting |
| 796.356 64 | Rink hockey |
| | Variant names: hardball hockey, quad roller hockey |
| 324.294 04 | The Nationals |
| | Former names: Australian Country Party, National Country Party, National Party of Australia |

The caption qualifier at 612.115 Coagulation (Clotting) indicates that coagulation and clotting are the same phenomenon. The variant names note at 796.35664 Rink hockey similarly indicates that rink hockey, hardball hockey, and quad roller hockey are all the same game, while the former names note at 324.29404 The Nationals indicates that Australian Country Party, National Country Party, and National Party of Australia all refer to the same political party.

Of the topics belonging to a class, some (e.g., those in class-here notes) are said to approximate the whole of the class. For some internal purposes (e.g., number building), all topics that approximate the whole of a class might be said to be equivalent. Independent semantic analysis, however, may or may not support such a characterization. An equivalence relationship holds between the topics named in the class-here note at 005.74015113 Mathematical logic—logic databases and deductive databases, but often, a different type of relationship (perhaps most often an associative relationship) holds between the multiple topics named in a class-here note. In the class-here note at 512.92 Algebraic operations, we have sibling relationships among the specific algebraic operations; in the class-here note at 808.5 Rhetoric of speech, it is difficult to identify which, if indeed any, particular relationship holds.

005.740 151 13 Mathematical logic

Class here logic databases, deductive
databases

512.92 Algebraic operations

Class here addition, subtraction, multiplication, division

808.5 Rhetoric of speech

Class here voice, expression, gesture

2.3. DDC classificatory structure and associative relationships

Associative relationships are generally understood as the varied set of semantic relationships that are not accounted for by hierarchical or equivalence relationships. Optimally, specific types of associative relationships can be identified, since without such specification, associative relationships cannot be used for much besides bringing the user's attention to another, potentially relevant, topic.

FRSAD (2011) mentions a number of specific associative relationship types, including Cause/Effect, Process/Agent, Action / Product of action, Raw material / Product, and so forth. Here is a context where the difference between the granularity of their basic units—a concept in a thesaurus vs. a class in a classification system—makes a real difference. The design of a bibliographic classification could easily incorporate topics interconnected by associative relationships into the same class. For example, at 730.92 Biography, the class-here note gathers together “description and critical appraisal of sculptors or plastic artists and their works”, alongside biographical material. (The parallel situation occurs for other, but not all, arts in the 700s.) But in 641 Food and drink, separate developments exist for 641.3 Food and 641.5 Cooking.

Associative relationships in the DDC are typically expressed through either class-elsewhere notes or see-also references. Like see references, such relationships are topical relationships, with the topic in the target class specified explicitly in the note/reference, while the topic in the source class must be inferred.

Giving the location of interrelated topics is only one of several functions of class-elsewhere notes. (Other roles include “[showing] preference order among topics, [leading] to broader or narrower topics in the same notational hierarchy, [overriding] the first-of-two rule, [and leading] to the comprehensive or interdisciplinary number for the topic” [Chan & Mitchell, 2003: 25].)

962.054 Administration of Anwar Sadat, 1970-1981

Class Israel-Arab War, 1973, in 956.048

415.92 Word formation

Including affixes (infixes, prefixes, suffixes), clitics; formation of compound words

Class here derivational morphology

Class etymology in 412

Numbers for historical periods in the span for 930–990 History of specific continents, countries, localities; extraterrestrial worlds are formed using notation from Table 2 for geographic area and area-specific notation for the period. The periods may be defined by political administrations (as is the case with 962.054 Administration of Anwar Sadat, 1970-1981), by periods of foreign rule / political alignments, of war, etc. The number 962.054 lies within the development for the history of Egypt and covers a span of 11 years, from October 1970 to October 1981. The Israel-Arab War, 1973 (a.k.a. Yom Kippur War) falls entirely within this time frame. The class-elsewhere note found at 962.054 is also found at 956.91042 Period of Republic, 1945–, where 956.91 introduces the development for the history of Syria, and at 956.94053 1967–1974, where 956.94 introduces the development for the history of Palestine/Israel.

In all three cases, the class-elsewhere note takes us to 956.048, where we find the following upward hierarchy:

956 Middle East (Near East)

956.04 1945–1980

956.048 Israel-Arab War, 1973 (Yom Kippur War)

Thus, for the Israel-Arab War, 1973, these class-elsewhere notes lead from historical period numbers for the principal countries involved in the war, Egypt, Syria, and Israel, to a number for an historical period for the wider region. The relationship between the war and any historical period is associative.

The class at 415.92 Word formation contains a class-elsewhere note that sends works on etymology away, to their own class. Unlike the example just examined, the relationship between word formation and etymology does not fit a regular pattern. Word formation refers to the process of forming new words through derivation or compounding, while etymology refers to the history of words and their origins. Thus, word formation stands at the beginning of a process that etymology stands at the end of; word formation may be part of the history of a word that etymology examines.

A systematic study of the semantic relationships expressed by class-elsewhere notes in the DDC has yet to be conducted. We anticipate identifying some productive associative relationships, but suspect that the associative relationships in many class-elsewhere notes will be of a relatively unique nature.

See-also references are said to “point to topics that are [only] tangentially related to the topic where the note is given” (Chan & Mitchell, 2003: 28). A study of see-also references in the DDC (Green, 2011) found relationships established on the basis of lexical similarity, complementarity, facet difference, and relational configuration difference, as evident in the following examples:

T2—764 252 Austin County

See also —76431 for Austin (city)

641.865 4 Cookies

Variant name: biscuits

See also . . . 641.8157 for biscuits (quick breads)

190 Modern western and other noneastern philosophy

See also 181 for eastern philosophy

621.91 Planing and milling tools

See also 671.35 for machining metal

616.075 Diagnosis and prognosis

616.075 61 Blood analysis

See also 616.15075 for diagnosis of diseases of blood

616.15 Diseases of blood

See also 616.07561 for use of blood analysis in diagnosis of diseases in general

616.150 75 Diseases of blood—diagnosis and prognosis

See-also references based on lexical similarity depend on the presence of two lexical items (words or phrases) that could be mistaken for each other. For example, the see-also reference at T2—764252 serves to differentiate between a county and a city in Texas with the same name (Austin); the reference is

especially needed because the city is *not* located in the county of the same name. At 641.8654, the see-also reference has its basis in the homonymy between the meanings of the word “biscuit” in American cooking and British cooking.

Complementary topics exhaust the universe with respect to some property. For instance, the scope of the development at 190 is noneastern philosophy; the see-also reference points to the complementary topic (eastern philosophy). See-also relationships are also used for topics that represent different facets of a subject. At 621.91, the emphasis is on the tools used for milling; at 671.35 the emphasis is on the object that is milled.

Finally, we also find see-also relationships linking complex topics that include the same topical components, but relate them in different ways. The end result is that the relationships among the topical components form different configurations. In the nearly reciprocal see-also relationships between 616.07561 and 616.15075, the relationships distinguish between diagnosis based on analysis of blood at 616.07561 and diagnosis used to identify diseases of blood at 616.15075.

Additional see-also references were based on real-world knowledge; their relationships did not appear to be generalizable.

2.4 DDC classificatory structure through the Relative Index

We have previously noted the role played by the DDC’s Relative Index in giving access to the DDC’s classified arrangement of classes through an alphabetically ordered set of terms. Access to the classification is achieved through Figure 1’s Relative-Index-Term-<reflects>-Topic relationship. Given this overarching relationship, we would expect to find essentially the same kinds of relationships / a parallel set of relationships in the Relative Index as we find in the classification itself, only now we consider the relationships from a lexical perspective.

The MARC authority format, which is used to store Relative Index data, provides for the capture of relationships between Relative Index terms. In this format, hierarchical and equivalence relationships between topics may be expressed using explicitly coded references between corresponding RI headings. Although only a small number of hierarchical and equivalence relationships have been coded at present in the DDC, many others can be identified automatically (Green, 2014). To some extent, this depends on the process of matching topics expressed by RI headings to topics expressed in class descriptions, which is not entirely straightforward (Green, 2008). For example, if RI terms can be matched to topics expressed in class descriptions, equivalence relationships expressed using caption qualifiers, variant name notes, and former name notes can be detected by virtue of those phenomena in class descriptions, as discussed in section 2.2.

Other equivalence relationships can be detected by comparing each pair of Relative Index terms that index the same number. One comparison looks for the replacement of a hyphen with a space (thus identifying the equivalence of “Full-text indexing” and “Fulltext indexing” at 025.486). Another comparison examines whether single word terms could be acronyms (thus identifying the equivalence of PRECIS indexing and Preserved Context Indexing System at 025.47).

The identification of yet other equivalence relationships among Relative Index terms takes advantage of matches between (a) RI terms and (b) Library of Congress Subject Headings (LCSHs) or variant access points. Processing such matches ferrets out Bliss Bibliographic Classification and Bliss Classification as equivalent terms at 025.434. Other equivalence relationships can be identified on the basis of matching RI terms with lexical entries in WordNet², a lexical database of English word senses, and of membership in the same WordNet “synset” (where a synset is a set of synonymous word senses). Processing these matches supports the equivalence of Bigfoot and Sasquatch at 001.944 and of Annuals and Yearbooks at 050.

The automatic identification of hierarchical relationships similarly can rely solely on internal data or can take advantage of connections with relationships in external data. In English, the phrase X A (in which X is likely to be an adjective modifying A) is typically more specific than A, especially if X A indexes a class that is subordinate to a class indexed by A. This heuristic supports the following relationship:

- Small-scale systems (003.7) BT Systems (003)
- Analytical bibliography (010.42) BT Bibliography (010)
- Pictorial journalism (070.49) BT Journalism (070.4)

Some hierarchical relationships between Relative Index terms are of the form A—X BT A, but others are of the form A—X BT X. We have identified some number of patterns that operate in one fashion or the other. On the basis of these patterns, we identify the following hierarchical relationships:

- Art metalwork—to 4000 B.C. (739.09012) BT Art metalwork (739)
- Museums—Washington (D.C.) (069.09753) BT Museums (069)
- Finance—library operations (025.11) BT Finance (332)
- Computer graphics—dictionaries (006.603) BT Dictionaries (413)
- Adolescents—libraries for (027.626) BT Libraries (027)
- Union catalogs—library cooperation (021.642) BT Library cooperation (021.64)

An important subset of hierarchical relationships is that in which A—X BT A and X names a discipline. Consider, for example, the RI Gambling—law. We can assert Gambling—law BT Gambling in that 306.482, the number indexed by Gambling, is its interdisciplinary number. That interdisciplinary number is

² Available online at <http://wordnet.princeton.edu/>.

broader than Gambling in the context of any specific discipline. Additional cross-disciplinary relationships are addressed in (Gnoli, De Santis & Pusterla, 2015).

Other hierarchical relationships can be identified on the basis of LCSH and WordNet data. For example, LCSH data supports the identification of a hierarchical relationship between the broader RI term Special libraries, which indexes 026, and the RI term Technical libraries, which indexes 026.6. WordNet data supports the identification of a hierarchical relationship between the broader RI term Computer networks, which indexes 004.6, and Internet, which indexes 004.678.

Automatic identification of associative relationships has not been attempted.

3. DDC classificatory structure and syntagmatic relationships

Although the DDC is not a fully faceted classification scheme, faceting underlies the development of portions of the system and is visible in many of its add instructions. Inter-facet relationships, which are syntagmatic in nature, have already been noted among the associative relationships in see-also references. Inter-facet relationships are also expressed with some degree of systematicity in the complex structure of many RI headings. Consider, for example, the number 787.871642, which is built with the following components:

787.87 Guitars
 (784-788:)1 General principles, musical forms, instruments
 (781.)642 Country music

and is indexed with the RI Guitars – music – country music. It is not necessarily the case that all components (main heading + subheadings) of a Relative Index term will match up on a one-to-one basis with the components of a built number, but often there is partial alignment. In such cases it is often possible to see syntagmatic relationships expressed systematically across a set of Relative Index headings, as is the case in Table 1.

4. Conclusions

If thesauri provide the prototypical pattern for subject authority control, it is because of the simplicity and clarity with which they express relationships. The basic pattern used is the assertion of a hierarchical, equivalence, or associative relationship between terms, each of which expresses a concept. Possible extensions to this pattern are the specification of type of hierarchical relationship (e.g., instance, whole-part) and expression of concepts through the conjunction (ANDing) or disjunction (ORing) of terms.

Table 1: *Correspondence between built number and Relative Index term components*

Base number	Component 1	Component 2	Relative Index term
787.87 Guitars	(784-788:)1 General principles, musical forms, instruments	(781.)642 Country music	Guitars – music – country music
787.87 Guitars	(784-788:)1 General principles, musical forms, instruments	(781.)643 Blues	Guitars – music – blues
787.87 Guitars	(784-788:)1 General principles, musical forms, instruments	(781.)644 Soul	Guitars – music – soul
787.87 Guitars	(784-788:)1 General principles, musical forms, instruments	(781.)65 Jazz	Guitars – music – jazz
787.87 Guitars	(784-788:)1 General principles, musical forms, instruments	(781.)654 Mainstream jazz (“including swing”)	Guitars – music – swing
787.87 Guitars	(784-788:)1 General principles, musical forms, instruments	(781.)66 Rock (Rock 'n' roll)	Guitars – music – rock

Subject authority control is, of necessity, more complicated in a classification system like the DDC. We add another basic unit, a class, to the mix. On the one hand, this means having to take the inherent nature of classes as a gathering place for like items into account. In the context of a bibliographic classification that “likeness” often encompasses a variety of relationship types, including associative relationships. (And we have seen that the expression of associative relationships in the context of the DDC needs further investigation.) On the other hand, the relationship between the topics that are part of the class and the Relative Index terms that index the class also needs accounting for. Doing so will require (1) establishing relationships between natural language expressions in class descriptions and Relative Index terms and (2) recognizing the roles played by specific note types and other features in the system. Direct relationships between Relative Index terms follow the thesaural pattern more closely than other aspects of the DDC, but the complex, pre-coordinate, nature of many RI terms adds further complexity to the situation.

Why does the relational side of subject authority control in a classification system like the DDC matter? The importance lies in the user tasks supported by these relationships, with the users including, minimally, developers of the classification system, persons providing crosswalks between knowledge organization systems, classifiers, and last, but not least, end users. FRSAD (2011: 34) sets forth three generic user tasks supported in part by relationships within a subject authority control system: finding subjects (and/or their appellations), identifying subjects (and/or their appellations), and exploring relationships between subjects (and/or their appellations). Practically speaking, a strong set of relationships is required in a subject authority control system for these purposes:

- to help developers maintain the system without introducing confusion,
- to support the establishment of crosswalks between systems that can assist in knowledge discovery when an end user searches with entry vocabulary from one system against

bibliographic records to which subject appellations from other systems have been assigned,

- to help classifiers assign most appropriate subject appellations to bibliographic records, and
- to help end users find the most appropriate resources for their needs.

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Rebecca Green is an assistant editor of the DDC, with specific responsibilities related to DDC training modules and investigation of relationships in the DDC, with a long-term goal of developing a topic-based version of the system to support automated applications. Other research interests include the ontological characterization of classes in classification systems, extension of the FRSAD model to accommodate a topic-centered view of the DDC, and automated methods for identifying the facet structure of a subject. Prior to joining OCLC, Rebecca was an associate professor in the College of Information Studies at the University of Maryland.