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Formal nursing terminology systems: a means to an end

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Abstract

In response to the need to support diverse and complex information requirements, nursing has developed a number of different terminology systems. The two main kinds of systems that have emerged are enumerative systems and combinatorial systems, although some systems have characteristics of both approaches. Differences in the structure and content of terminology systems, while useful at a local level, prevent effective wider communication, information sharing, integration of record systems and comparison of nursing elements of healthcare information at a more global level. Formal nursing terminology systems present an alternative approach. This article describes a number of recent initiatives and explains how these emerging approaches may help to augment existing nursing terminology systems and overcome their limitations through mediation. The development of formal nursing terminology systems is not an end in itself and there remains a great deal of work to be done before success can be claimed. This article presents an overview of the key issues outstanding and provides recommendations for a way forward.

Keywords: terminology systems, nursing, concept representation

Introduction

In common with other health care professionals, nurses need a range of information to carry out their work. They need information on: individual clients, groups of clients, the environment in which they practice, and the current state-of-the-science [1]. They use information for different purposes including: to communicate with others, to make decisions, to make new knowledge through aggregation, and to find other information [2].

The majority of information traditionally generated and used by nurses takes the form of natural language *e.g.* speech and handwriting. As electronic record systems have been developed, so questions have arisen about how best to record this information so that it accurately reflects client experiences and nursing phenomena. Natural language is one option. However, while natural language makes clinical information available to nurses, it remains largely inaccessible to computer applications that manipulate clinical information symbolically *e.g.* for statistical research or automated decision support [3]. Such applications require data that is encoded according to 'standardized' terminology systems and data structures.

In this article we describe and critique a number of commonly reported nursing terminology systems, providing reasons for the recent proliferation of such systems. We present a solution for many of the problems arising from this proliferation and discuss outstanding issues for the nursing profession.

Existing nursing terminology systems

Terminology work within nursing has been ongoing for a number of years. Since the early 1990s a number of factors have conspired to provide a particularly fertile ground for the development of nursing terminology systems. These factors have included the need to quantify nursing for the management of resources, the development of the electronic patient record, the development of knowledge bases and the growth of evidence-based practice [4]. Above all, there has been a desire to ensure the visibility of nursing in healthcare systems: to ensure that systems are developed which support the work of nurses within a multi-disciplinary service; and to ensure that the contribution of that work is represented in aggregated healthcare information. The ongoing work has resulted in the development of a number of diverse nursing terminology systems.

Enumerative systems

Many nursing terminology systems are presented as, or are indexed by, a restricted set of pre-coordinated terminological phrases (in which concepts are combined to make a clinical phrase), arranged in a list and perhaps organised alphabetically or hierarchically. Such terminology systems are *enumerative* systems, meaning that all possible phrases are explicitly listed. Examples of enumerative systems include the North American Nursing Diagnosis Association Taxonomy I (NANDA) [5] and the Nursing Interventions Classification (NIC) [6].

NANDA is an example of an enumerative terminology system for nursing diagnoses. Within NANDA a nursing diagnosis represents a clinical judgement about the response of a client or client group to health issues. The current version embodies 155 nursing diagnoses, each with a label (a pre-coordinated phrase such as *Ineffective individual coping*), an informal definition (*i.e.* a definition written in natural language, rather than a more formal representation of concepts and relationships), defining characteristics, risk factors and/or related factors. Each nursing diagnosis is located within a simple organising structure consisting of 9 human response patterns.

NIC is also an example of an enumerative terminology system. The focus for NIC is on nursing interventions. Within NIC a nursing intervention represents a treatment, based on clinical judgement, that a nurse performs to enhance outcomes. The current version embodies 486 nursing interventions, each with a label, an informal definition, a list of activities that describe what a nurse does to implement the intervention, a unique non-hierarchical code and a short list of background readings. In common with NANDA, each intervention is located within a simple taxonomy, this time consisting of 7 classes and 30 domains.

Combinatorial systems

Several other nursing terminology systems employ a combinatorial approach, where complex terminological phrases may be built up from elementary concepts. So the NANDA phrase above might be represented as a combined concept consisting of three elements: *ineffective* (from a set of judgement concepts), *individual* (from a set of client concepts) and *coping* (from a set of human response concepts). Examples of such combinatorial terminology systems include the Omaha System [7], the Home Health Care Classification system (HHCC) [8] and the International Classification for Nursing Practice (ICNP[®]) [9]. This section focuses on the Nursing Intervention components of each of these combinatorial systems in order to demonstrate the range of approaches used.

The Omaha System provides a framework for documentation within home health and public health nursing practice. The Omaha System Intervention Scheme is organised into 3 levels of abstraction: 4 broad categories of interventions, 62 targets or objects of nursing action, and client-specific information (which is generated by the health care professional). The intervention categories each have a label and an informal definition and they seek to provide an organising structure for describing nursing actions. These categories are: *Health Teaching, Guidance and Counseling; Treatments and Procedures; Case Management; and Surveillance*. Targets, the ‘objects’ of nursing actions, serve to further describe interventions (giving rise to 248 potential phrases) *e.g. Surveillance – Nutrition*. They are arranged in a simple list; each has a label and a brief informal definition. Additional client-specific information may be added by the health professional to categories and targets.

In contrast, HHCC, which provides a framework for documenting and classifying home health and ambulatory care, allows nursing interventions (similar to targets in the Omaha System) to be qualified by the type of nursing action (similar to intervention categories in the Omaha System). The HHCC system of Nursing Interventions consists of 160 nursing interventions, each with a label, a short informal definition and a hierarchical code. Within the classification of nursing interventions, each nursing intervention is located within a hierarchy of 60 major categories and 100 subcategories *i.e.* subcategories are classified according to the generic ‘is-a’ relation under major categories. Nursing interventions, either categories or subcategories, may be modified by one of four types of nursing action: *Assess; Direct Care; Teach; and Manage* (giving rise to 640 potential phrases) *e.g. Breathing exercises – teach*.

These latter two terminology systems in reality represent hybrid approaches that display characteristics of both enumerative and combinatorial approaches. The ICNP[®] classification of Nursing Interventions goes somewhat further towards a combinatorial system by breaking down terminological phrases into eight different axes: *Action Type, Target, Means, Time, Topology, Location, Route, and Beneficiary* (giving rise not to hundreds but to many millions of potential phrases).

Difficulties with existing approaches

Enumerative and combinatorial systems are considered important because they provide a structure for retrieving and using nursing data from computer-based information systems [10]. Enumerative systems are also seen as useful for statistical evaluation [11]. However, there are difficulties associated with both approaches [12].

Despite relatively widespread use of enumerative systems, it is now recognised that an enumerative approach is inherently problematic. As mentioned previously, nursing care consumes and produces a large amount of detailed information. An enormous number of individual terminological phrases would be needed to represent all possible information. However, the constraints imposed in the development and use of enumerative systems mean that the number of phrases necessarily must be limited. Thus enumerative systems tend to reflect a compromise between being broad but shallow to cover many areas of interest, and being narrow but deep to provide the necessary detail for a specific area. As a result they must be tuned to a particular purpose if they are to be useful.

Combinatorial systems address this problem by permitting the representation of a larger number of more highly detailed concepts (although despite their increased expressiveness, there is evidence to show that combinatorial systems still do not in fact provide adequate coverage [13]). However, the lack of rules for determining relevant combinations means that the direct use of combinatorial systems introduces an increased 'look up' burden on users; in order to specify a single combined concept they must search for and select elements from several distinct lists. In addition, within such systems elementary concepts may be explicitly classified *e.g.* in HHCC nursing intervention subcategories are classified under major categories; combined concepts (*e.g.* a nursing intervention plus a type of nursing action) are not. For example a combined concept representing the phrase *Teaching about diabetes* would not be classified as a kind of *teaching* so retrieval of all interventions which involve teaching would not be straightforward. Thus in the absence of adequate supporting software, any hierarchical relationships between combined concepts must be inferred [14]. Other researchers have found related problems with the combinatorial approach. For example, in a recent review of the beta version of ICNP[®] the researcher concluded that it 'does not even remotely meet the fundamental requirements of a contemporary classification' [15, p.48].

Individual terminology systems can be useful if they match the requirements of particular users [16]. However, due to differences in content and structure we are not able to make use of their similarities and resolve their differences [17]. With such a diversity of different systems we cannot hope to communicate effectively, to share information, to build integrated record systems, and make sense of health care at a more global level. And yet this is what health care increasingly demands. It would be unrealistic to expect all potential users to use a single terminology system; indeed it would be unrealistic to expect anyone to develop such a system in the first place. Thus some form of mediation among existing nursing terminology systems is required, possibly through the use of formal terminology

systems, in order to facilitate the comparison and interchange of heterogeneous patient care data. Such systems will allow nurses to take full advantage of the data they collect and they will facilitate the ongoing transition to computer-based information systems.

Emerging approaches

A formal terminology system has three main components: a terminology model, a representation language and a software system [18]. A terminology model is a representation of a set of concepts and their interrelationships. For example, a terminology model for a nursing intervention might include concepts that relate to the target of an intervention (*e.g. Pain*) and type of action used (*e.g. Assessment*). Formal terminology systems are computer-based. To this end the model is constructed under a representation language that is implemented by a software system.

GALEN (Generalised Architecture for Languages, Encyclopaedias and Nomenclatures) is a research and development programme with a focus on technologies to underpin the next generation of clinical information systems. Under the GALEN approach, GRAIL (GALEN Representation and Integration Language) is the language used for the representation of concepts and their interrelationships [19]. GRAIL is one of a family of representation languages known as ‘description logics’.

Insert figure 1 around here

Two integrated sets of tools are used in the construction of a GRAIL model: a modelling environment and a terminology server. The modelling environment facilitates the formulation of models. This includes the specification of an initial hierarchy of elementary concepts and the definition of rules to decide how more complex concepts might be composed (Figure 1).

The terminology server performs the actual construction of the model [20]. This involves the composition of concepts according to the rules, the automatic classification of complex concepts into the hierarchy and conflict resolution (Figure 2).

Insert figure 2 around here

Another example is based on SNOMED[®] International, a large-scale multidisciplinary terminology system developed by the College of American Pathologists. Within the SNOMED[®] Reference Terminology (SNOMED[®] RT) [21] concepts and their interrelationships are represented using a different description logic than under the GALEN approach (*i.e.* modified Knowledge Representation Specification Syntax [KRSS]). In common with the GALEN approach, a set of tools supports the formulation and construction of the SNOMED[®] RT terminology model. An additional recent initiative, SNOMED[®] Clinical Terms (SNOMED[®] CT), represents an attempt by the College of American Pathologists and the UK Secretary of State for Health (on behalf of the National Health Service Executive) to combine SNOMED[®] RT and UK Clinical Terms Version 3. These two latter examples represent attempts, not only to mediate among existing nursing terminology systems, but also to integrate nursing concepts within larger terminology systems with a broad coverage of the healthcare domain. The scope of work for a current International Standards Organization (ISO) initiative on the integration of a reference terminology model for nursing is consistent with this perspective.

Outstanding issues

The GALEN approach, SNOMED[®] RT and SNOMED[®] CT, seek to provide formal terminology systems within which all and only clinically sensible concepts (both elementary and complex) are represented and classified. There is plausible evidence to suggest that formal terminology systems can accommodate different representational forms *i.e.* both enumerative and combinatorial systems, and they can identify and exploit hierarchical relationships within and between such systems [22] (Figure 3).

Insert figure 3 around here

In this way formal terminology systems function as so-called *reference terminologies* [21]. By linking concepts in a formal terminology model to phrases from diverse terminology systems, formal terminology systems can act as a common point of reference to highlight semantic overlap and difference. Formal terminology systems are emerging

as a possible solution to the mediation problem. However, at least as far as nursing goes, there are a number of outstanding issues. These issues form the focus of the remainder of this article.

Formal modelling of existing nursing terminology systems

There may be any number of ways to model terms drawn from existing terminology systems. For example, should we model *Impaired swallowing* as a ‘swallowing that is modified by an impairment’ or as an ‘impairment that is modified by swallowing’? Is a *Client* a beneficiary, a subject or a recipient of care? Each view has its own merits. However, practical experience within standards organisations demonstrates that reaching consensus on such issues is problematic. In practical terms it may not matter that we reach consensus. Unlike with more traditional terminology systems, formal terminology systems encourage a more pragmatic solution by re-framing the problem. Key questions we should be asking of a formal terminology system are not ‘What does it look like?’ and ‘Does it fit with my view of the world?’. Rather we should be asking ‘Does it behave as I expect?’ and ‘Does it behave as I want?’. For example, when a concept is automatically classified it should appear where it is expected to appear. Moreover, other similar concepts should be classified in a similar way. For example, we would expect conceptual representations of *Chronic pain* and *Acute pain* to appear as close siblings under the more general conceptual representation of *Pain*. There may of course be disagreement about the resulting classifications within formal terminology systems. However, any debate is likely to be more concrete than philosophical.

Idiosyncrasies of existing terminology systems

Existing enumerative and combinatorial systems have a number of idiosyncrasies. Certain features make them suitable perhaps for statistical evaluation but less appropriate in a clinical context. For example while we might code something as an ‘Other....’ we would not necessarily wish to record such a vague notion in the clinical record. Other features such as embedded actions (*i.e.* doing z, doing y to do z, doing x to do y to do z, *etc.*) make retrieval more difficult. And as a final example, many existing terminology systems have been developed as *user interface terminologies* *i.e.* terminologies that are optimized for user interface applications [21]. Therefore a level of redundancy is tolerated that would not be desirable within formal systems. In developing formal models to represent existing terminology systems we can identify inconsistencies within those systems and lobby to effect positive change.

Consistency in modelling without ambiguity in interpretation

A further outstanding issue concerns the level of abstraction at which existing terminology systems map onto the formal terminology system. One study has shown that the informal nature of definitional statements in existing terminology systems is not exact enough for consistent concept modelling and that greater success comes from taking labels rather than definitions as sources for concept models [22]. However the same study also showed that lexically similar or identical labels are not considered by developers or users necessarily to mean the same thing *e.g.* *Medication Actions – Teach* from HHCC and *Health Teaching, Guidance, and Counseling – Medication Action/Side Effects* from the Omaha System. So while it may be easier to represent more abstract concepts, the abstraction belies a greater potential for ambiguity and inaccuracy in mapping. A possible solution might be to use a formative development methodology that accommodates both the views of terminology developers and users in determining the existence and accuracy of mappings.

Scope

As demonstrated previously, formal terminology systems can be used to perform terminological reasoning *e.g.* ‘Acute pain’ is a child of ‘Pain’. However, it would be wrong to expect such systems to perform other forms of non-terminological reasoning. Examples of such inferences might include: links to appropriate interventions given a particular diagnosis, or the derivation of a particular diagnosis from a set of signs and symptoms. While formal terminology systems must contain the basic building blocks or semantic ‘hooks’ to enable such inferences to be made *i.e.* expressions to represent signs, symptoms, diagnoses, interventions, *etc.*, clinical decision-making and diagnostic inference are usually beyond their scope.

Internal coherence versus clinical validity

People are not machines and machines are not people. The needs of one do not in many cases equal the needs of the other. Because a concept is coherent and follows the logical rules of a formal terminology system, this doesn’t necessarily mean that it will be valid or even relevant in clinical practice. For example, it may be desirable to specify a general rule to associate a phenomenon with a colour. While this would allow us to capture the notion of *Green sputum* it would also allow inappropriate concepts such as *Yellow pain*. It is not essential that the formal terminology system contains only clinically relevant concepts; indeed it is very unlikely. However, if we cannot identify and

isolate subsets of valid concepts that have relevance to particular domains (*e.g.* paediatric nursing), tasks such as defining and maintaining mappings will be problematic. This will require advanced stakeholder and task analysis and compatible mechanisms to capture the results of such analyses.

With respect to internal coherence, it would be very difficult to develop a formal nursing terminology system without flaws. We accept that people are flawed - in many cases we expect it and we develop processes to identify and overcome those flaws in order to prevent error *e.g.* third-party verification of intravenous drug dosage. To expect more of a computer-based formal terminology system would be unrealistic. However, unless there is some way of identifying and overcoming such flaws there is the very real danger of unchecked error *e.g.* automated administration of an incorrect drug dosage due to an unidentified flaw within the formal terminology system.

Generalizability

As other authors have noted 'there is as yet no proof that a general re-usable terminology serving all of the aspirations for clinical information systems is possible' [1, p. 241]. To develop a formal terminology system that covers all of healthcare will require enormous effort; but to be useful as a reference terminology, any formal terminology system must necessarily provide broad coverage. The formal terminology system approach has been successfully applied within specific, clearly delimited domains [22]. However, it is important to acknowledge that there is no firm evidence to suggest that the approach can be generalised to include other related and disparate domains.

Usability

The logical foundation of formal terminology systems does not in many cases tally with the more pragmatic concerns of users. Initially, as formal terminology systems are used solely for mediating between existing terminology systems, any formal properties are only of concern to the people who have to build and maintain the system (including those who must maintain the mappings to existing systems). Inevitably there will be a gradual migration towards direct use of formal terminology systems for documentation, querying, reporting and other more clinical and user-oriented functions. The development of SNOMED[®] CT, a clinical terminology with both reference and interface characteristics is an indication of such a migration. However this cannot happen without the concurrent development of other mechanisms for presenting the formal terminology system to users and for 'feeding

back' user input to the system *e.g.* models of the dialogue between the embedded terminology system and the computer-based application user that would embody also the non-terminological knowledge described previously.

Application-based validation

Formal terminology systems are best viewed as software. Moreover, if it weren't for the desire to build advanced computer-based applications, the development of formal terminology systems would be little more than an interesting academic exercise [1]. Such applications are potentially a confounding factor in the utility and usability of formal terminology systems. Thus an accurate evaluation of formal terminology systems can only take place in the context of the computer-based applications in which they are embedded. Traditional bench testing techniques in which the terminology system is evaluated separately from the application should form only a small part of any systematic evaluation.

Future-proofing

As mentioned previously, enumerative and combinatorial systems may not provide adequate coverage of the nursing domain (given the wide range of potential purposes this is perhaps unsurprising, particularly if terminology systems are evaluated at a snapshot in time). Mechanisms such as formal terminology systems, whose primary role is to mediate between existing terminology systems, can do nothing to overcome this limitation. The onus is on the developers of existing terminology systems to augment and refine their systems in response to the changing needs of users and to advances in nursing science. Formal terminology systems must be able to accommodate or adapt to changes to their source terminology systems in a timely fashion; in particular, the high-level conceptual structure (*i.e.* the ontology) must be resilient enough to cope with shifting paradigms in nursing science.

Conclusion

Formal terminology systems represent new ammunition against the so-called 'terminology problem'. Formal terminology systems do not seek initially to replace existing systems. Instead they seek to supplement them, increase their utility and drive them to a more principled organisation. However, it is important to maintain realistic expectations - there is no proof as yet that the development of such systems on a large scale is possible. Moreover, before we can claim any degree of success, their development depends on a number of factors:

- There is a need to build on important ground work by adopting a formative approach to development and by developing appropriate consensus-building tools and techniques, such as a modified Delphi technique, for evaluating formal terminology systems both in terms of their behaviour and in terms of more traditional measures *e.g.* content coverage. This of course means evaluating the systems in the context of the applications in which they are embedded.
- Due to their inherent complexity, formal terminology systems will inevitably have flaws. It would be overly ambitious to expect otherwise. Thus there is a need to develop mechanisms for identifying and overcoming such flaws as they are discovered, particularly where client safety and data integrity are at risk.
- In an increasingly interdisciplinary world it is also important that formal nursing terminology systems are not developed in isolation, but form part of more comprehensive terminology systems that cover a broader range of healthcare.
- Formal terminology systems are necessarily computer-based. They embody constructs and exhibit behaviours that would be unacceptable to clinical users. Thus, external supporting mechanisms, such as dialogue models are needed before we can even contemplate direct use of formal terminology systems.
- Where formal terminology systems function as reference terminologies, there should be a ‘contract’ between reference terminology system developers and users, so that users can assess and manage the risk of change, such as the impact on sources.
- It is important to recognise the boundaries of terminological reasoning and to develop and use formal terminology systems appropriately. Formal terminology systems generally cannot perform diagnostic inference or clinical decision-making; they can however be used to provide semantic ‘hooks’ to other applications that may be optimised for such non-terminological reasoning.
- There is a relative paucity of applications that currently depend on formal terminology systems. We must await other applications and more widespread use before we can appreciate fully the true utility of formal terminology systems.

To a large extent, formal nursing terminology systems represent a new paradigm for nursing, for nursing terminology development, and for nursing informatics. Nursing, with its traditional emphasis on holism and caring

will find it difficult to accept and integrate such a paradigm into practice. Nursing is necessarily individualised in nature. Therefore to attempt to standardise it would seem to many to be a strange activity. However, formal terminology systems do not seek to standardise nursing. They seek instead to formalise the terminology used within nursing.

Without formal terminology systems, nursing inevitably will be impoverished. It will not be possible to make full use of the information currently recorded by nurses, to document nursing's contribution to client care outcomes, and to build practice-based nursing knowledge. More importantly perhaps, it will not be possible to advance significantly nursing informatics to a state where we can build on important ground work and begin to develop advanced applications such as a truly computer-based patient record or computer-assisted decision support systems. Formal terminology systems are not an end in themselves. They are a means to fulfil a greater potential for nursing informatics and for the profession as a whole.

However, the development, application and validation of formal terminology systems will not be easy. It will require a commitment on the part of both the nursing informatics community and the nursing profession. We believe that without such systems, progress in nursing informatics will be at best very slow. They are essential if we are to advance the state-of-the-science to a point where we can explore and make full use of the power of computers.

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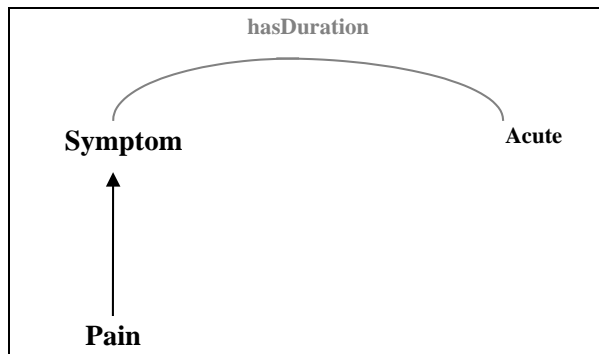


Figure 1: A diagrammatic representation of a GRAIL model in which the concept **Pain** has been explicitly defined as a child of **Symptom**. A rule (represented as an arc labelled with **hasDuration**) states that it would be reasonable to combine **Symptom** with **Acute** via the **hasDuration** attribute. This rule is inherited by **Pain** as it is a child of **Symptom**.

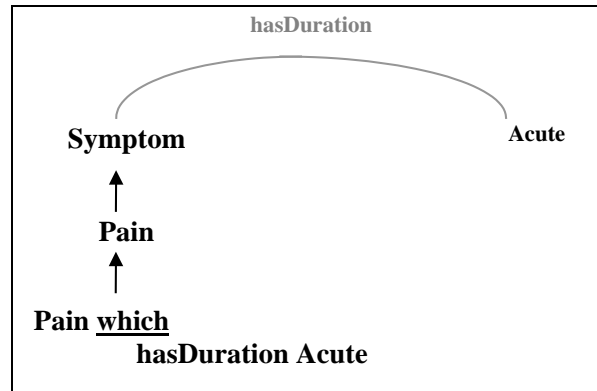


Figure 2: Diagrammatic representation showing how the complex concept *Pain which hasDuration Acute*, corresponding to the notion 'Acute pain', has been classified automatically by the terminology server as a child of *Pain*.

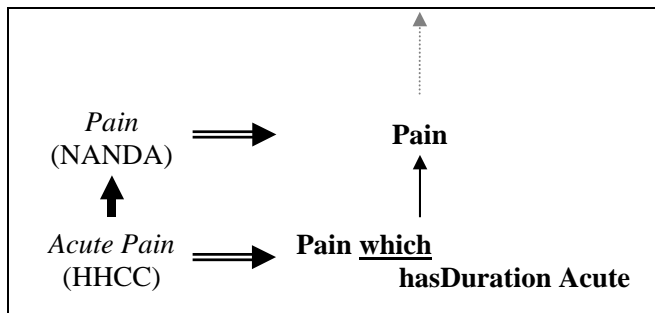


Figure 3: Diagrammatic representation showing how the hierarchical relationship between the conceptual representations for 'Acute pain' and 'Pain' can be exploited to suggest a nearest match i.e. a mapping from 'Acute Pain' from HHCC to 'Pain' from NANDA.