Computational Ontologies as Classification Artifacts in IS Research

Completed Research

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Abstract

Based on previous work on classification in IS research, this paper reports on an experimental investigation into the use of computational ontologies as classification artifacts, given the classification approaches identified in information systems (IS) research. The set-theoretical basis of computational ontologies ensures particular suitability for classification functions, and classification was identified as an accepted approach to develop contributions to IS research. The main contribution of the paper is a set of guidelines that IS researchers could use when adopting a classification approach and constructing an ontology as the resulting classification artifact. The guidelines were extracted by mapping an ontology construction approach to the classification approaches of IS research. Ontology construction approaches have been developed in response to the significant adoption of computational ontologies in the broad field of computing and IS since the acceptance of the W3C standards for ontology languages. These W3C standards also resulted in the development of tools such as ontology editors and reasoners. The advantages of using computational ontologies as classification artifacts thus include standardized representation, as well as the availability of associated technologies such as reasoners that could, for instance, ensure that implicit assumptions are made explicit and that the ontology is consistent and satisfiable. The research results from this experimental investigation extend the current work on classification in IS research.

Keywords (Required)

Classification, Classification in IS, Computational Ontology, Ontologies, Reasoners, Taxonomy, Typology, OWL.

Introduction

The concept of ontology originated in philosophy as the *study of being* (Smith 1982), but since research breakthroughs in the development of decidable fragments of logics such as description logics (DLs), ontologies have become commonplace in computing (Horrocks, Patel-Schneider, et al. 2003). The term *ontology* is currently widespread in information systems (IS) and could refer to anything from a domain vocabulary, conceptual model or class diagram, to a formal computational ontology (Horrocks, McGuinness, et al. 2003). In the context of computing an ontology is defined as a formal, explicit, computer readable specification of a conceptual model of a particular domain (Guarino et al. 2009). Computational ontologies are constructed using an ontology language with a formal knowledge representation basis. Nowadays the most widely accepted ontology languages are the standards for the Semantic Web language stack specified by the World Wide Web Consortium (W3C), such as RDF, RDF Schema and OWL[1] (Berners-Lee et al. 2001; Gerber 2006; Gerber et al. 2007). Ontologies developed

[1] RDF or Resource Description Framework is a standard model for data interchange on the Web (W3C 2014a). RDF Schema extends the basic RDF vocabulary and specifies a set of classes with certain properties using the RDF data model (W3C 2014b). OWL, the Web Ontology Language, is a computational logic-based language based on description logics (DLs) and extending RDF and RDF Schema (W3C 2013).

using OWL are particularly suitable for classification functions because the model-theoretic semantics of OWL ontologies are set-based (Grau and Motik 2008), and this fact led to the formulation of the objective of this research, namely to investigate how ontologies could be used to support the classification approaches identified in IS research. In particular, IS classification approaches are mapped to the steps of the ontology engineering approach of Horridge (Horridge 2011). These results should enable IS scholars interested in classification to use computational ontologies and ontology technologies to develop classification contributions in support of their research.

The remainder of this paper is structured as follows: the next section provides background information on classification, followed by a discussion on computational ontologies and their construction, as well as computational ontologies as classification artifacts. The subsequent section presents the experimental investigation, starting with a discussion on classification in IS, which is followed by the mapping of the ontology construction method to the classification approaches identified in IS research.

Background

Classification

Classification is a fundamental human endeavor in response to our need to organize and describe the things in the world around us, as well as to identify with social structures. Recent research in neuroscience suggests that classification and categorization are more fundamental to the human brain than previously thought (Martin and Caramazza 2003). In research published by Mahon et al. (2009), it was found that category organizations in the brain are not dependent on sight, and Huth et al. (2012) measured brain activity and found that the brain is organized in a continuous semantic space representing object and action categories that are shared among individuals. The results of classification evident in human classifications systems, even though often implicit, have an impact on all levels of society. Psychology and sociology research documented, for instance, *implicit association* with social categories and the effects thereof, such as the negativity towards mathematics as subject that female students often demonstrate (Nosek et al. 2002). The effects of classification are also observable in social phenomena based on categorization, such as social identity, stereotyping and labeling, and the often associated prejudices (Foroni and Rothbart 2013). In socio-technical systems we sometimes only become aware of classification when misclassification is detected, for instance, when German Daimler-Benz listed on the New York stock exchange in 1993, the company was confusingly classified as both *profit-bearing* and *making a loss* (Radebaugh et al. 1995)[2].

Scholarly writings on classification and how humans approach classification and categorization can be found in documents from antiquity, for instance by Aristotle and Plato (Parrochia and Neuville 2013), to current research publications in the natural sciences (Cotterill 1995; Linnaeus 1758; Pavlinov 2013), the information sciences (Dewey 1876; OCLC 2016; UDC 2017), the social sciences (Bailey 1994; Marradi 1990) and computing (Amgoud and Serrurier 2007; Gordon et al. 2007). Classification is actively studied in philosophy, mathematics and language studies (Baele 2010; Cohen and Lefebvre 2005; Craig 1983; Jacob 2004). In machine learning and statistics, classification techniques or classifiers are systematic approaches applied to build classification models or organize data or observations into categories and sub-categories on the basis of an input data set (Fayyad et al. 1996; Michie et al. 1994). Some of the original work demonstrating direct application of classification is evident in the management sciences where scholars developed an organizational taxonomy and organizational systematics from the principles of systematics in biology in order to provide insight into the nature and evolution of organizations (McKelvey 1982, 1987; Pinder and Moore 1979; Rich 1992).

Parrochia and Neuville (2013) define classification as the activity of categorizing or organizing objects into concepts, classes or groups according to their similarities and differences, or their relation to a predetermined set of criteria. *Categorization* is the process that sorts things, objects (or ideas) into *categories* that can be used to recognize, differentiate, order, understand and explain the world, while *conceptualization* is the process that defines concepts where a *concept* is regarded as a more abstract category (Cohen and Lefebvre 2005; Jacob 2004; Roasch and Lloyd 1978).

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[2] Under German GAAP (Generally Accepted Accounting Principles) Daimler-Benz was classified as a profit-making entity (a profit of DM 615 million), while under U.S. GAAP the same company made a loss of DM 1 839 million.

The products of classification, such as schemas, taxonomies, classifications (noun), typologies and ontologies necessarily describe and organize things or objects. Some notable classification systems are the Mathematics Subject Classification that provides a standard taxonomy for mathematics (Nature 2018), the Library of Congress MARC 21 Format for Classification Data that provides detailed descriptions of data elements (LOC 2017), and ICD10 specified by the World Health Organization and used internationally to, for instance, classify diseases (WHO 2017). With regard to the naming of classification artifacts, a distinction is often made between terms such as taxonomy and typology, even though their general purpose is the same. Taxonomies are often seen as exhaustive, hierarchical lists describing relationships between items (e.g. the Linneaen taxonomy that describes and categorizes the natural world (Linnaeus 1758)) and typologies are defined as non-exhaustive lists grouping items according to their similarities (Bailey 1994; Fiedler et al. 1996).

Computational Ontologies and their Construction

When investigating the meaning of the term ontology, its philosophical roots are soon evident. Webster's Dictionary defines an ontology as a *branch of metaphysics relating to the nature and relations of being* or *a particular theory about the nature of being or the kinds of existence* (Merriam-Webster 1882). However, the meaning of the term *ontology* evolved when it was adopted in different disciplines such as artificial intelligence (AI), where the term *ontology* describes a knowledge representation artifact based on logic (Dieter Fensel 2001). The developments in computational logic, specifically the development of description logics (DLs), led to the notion of *computational* ontologies (Baader 2007; Hustadt et al. 2004). A computation ontology is *a formal, explicit specification of a shared conceptualization* (Guarino et al. 2009). Computational ontologies provide a mechanism to capture qualitative descriptions and assertions about concepts or classes, as well as relations representing a domain using a logic-based ontology language. A user constructs an ontology by declaring sets of assertions or syntactic sentences, also referred to as axioms, using an ontology language such as OWL. These assertions represent the knowledge that the user wants to capture given a specific domain of interest. An assertion is typically composed of classes, relations or instances (Horridge 2011)[3]. Classes are used to represent categories, relations link classes and instances belong to or are related to classes. OWL, the Web Ontology Language, is based on DLs and the latest version of the OWL standard (OWL2[4]) was published in 2012 (Krötzsch 2012). In response to the W3C standards, tools such as ontology editors, reasoners and development environments that exploit ontology functionality, for instance by making use of the standard OWL2 API, were developed (OSF Wiki 2014; owl.cs 2016; W3C 2015). The ontology editor Protégé (Stanford BMIR 2016) with some of its packaged reasoners such as Fact++ (Tsarkov 2007) and Pellet (Sirin et al. 2007), emerged as one of the most frequently adopted editors for computational ontology construction, which also served as motivation for the adoption of Protégé for this study.

A logic-based ontology language such as OWL that is based on DLs allows for algorithms in reasoners to exploit the logic base and draw inferences from the ontology assertions (Corcho et al. 2003; Horrocks, Patel-Schneider, et al. 2003). DLs have precise model-theoretic semantics and it is therefore possible not only to query ontologies, but compute inferences or implicit knowledge through reasoning over the set of explicitly stated assertions (or descriptions) used to construct ontologies (Baader et al. 2003; Kleene 2002). The reasoners packaged with Protégé implement some standard reasoning services such as *satisfiability testing* (the process of determining if a class contains any instances or individuals such as if the class is a valid class given the domain representation), *subsumption testing* (ascertaining whether a class is a sub-class or a super-class of another), *consistency checking* (testing that the set of assertions made in the ontology about classes do not contain any explicit or implicit contradictions), and lastly *instance checking* (determining whether a specific instance within an ontology belongs to a class or complex class). Subsumption testing determines the 'is-a' relation often used in ontology engineering to represent the *taxonomy* of an ontology or the hierarchy of classes from the general to the specific (Brachman 1983). Furthermore, a class or concept is said to be *unsatisfiable* if the reasoning detects that it cannot have any individuals or instances, and an ontology is *inconsistent* if the ontology asserts explicit or implicit contradictions.

[3] Ontology terminology varies, and the terms concepts, roles and individuals are often used instead of classes, relations and instances respectively.

[4] OWL2 is a family of ontology languages based on description logics

With regard to ontology construction, several methodologies for the construction of ontologies have been developed and the variation in these methodologies could be ascribed to the different purposes envisioned for the specific ontologies (Iqbal et al. 2013). For example, Methontology (Fernández-López et al. 1997) and methods that include ontology life-cycles (Neuhaus et al. 2013) are well cited ontology engineering methodologies. Ontologies that are constructed for the purpose of a shared vocabulary require methodologies that ensure consensus is reached by the community (Ashburner et al. 2000; Hepp et al. 2006). Methodologies that focus on ontology integration and interoperability emphasize the adoption of shared upper ontologies during ontology construction (Oberle et al. 2007; Obrst et al. 2006). The NeOn project developed a comprehensive methodology framework that aims to address all activities and pathways relevant to ontology development, including ontology re-engineering, ontology alignment, modularized ontologies, ontology design patterns and the integration of relevant resources such as folksonomies or thesauri (Suárez-Figueroa et al. 2012).

In spite of the variety in ontology engineering methodologies, core activities for ontology construction are distinguishable, namely establishing the purpose of the ontology and the competency questions, as well as identification, description and definition of the classes, relations and where applicable, instances (Noy et al. 2001; Staab and Maedche 2000). One of the popular methodologies for the construction of OWL2 ontologies proposed by Horridge (2011) focuses primarily on these core activities through a tutorial. This method (referred to for the purpose of this paper as the Horridge method) was adopted for the purpose of this investigation. The Horridge method focuses on core ontology construction activities as well as supplied examples, which assist with indicating how ontologies support classification in this study. A short summary of the Horridge method is thus provided: After identifying the basic *named classes* for a pizza as well as characteristics for these classes, class hierarchies (using super- or sub-classes implying subsumption or the `is-a` relation) are constructed (Horridge 2011, p. 22). OWL object properties are then used to model relations[5]. When defining relations using object properties, OWL allows for asserting several additional property characteristics such as functionality, transitivity and domains and ranges (Horridge 2011, pp. 23–35). Refining the pizza ontology entails the definition of classes using existential and universal restrictions using object properties[6]. After specifying a hierarchy of *named classes* such as could be found in a menu (Horridge 2011, p. 48), analysis is done of *characteristics* that are unique to certain kinds of pizzas such as vegetarian pizzas that do not contain any meat (Horridge 2011, p. 60,75). The remainder of the Horridge method and the tutorial discuss the use of standard reasoning packaged with Protégé to refine definitions, derive implicit consequences and assert necessary and sufficient conditions, closure axioms, disjoint and covering axioms and cardinality restrictions. The tutorial concludes with a discussion on instances, i.e. how to assert class membership and how to use reasoning, given instances.

Computational Ontologies as Classification Artifacts

Even though the terms *ontology* and *classification* often appear together in publications, such as when reasoning or ontology learning is discussed (Glimm et al. 2012; Grau et al. 2010; Weng et al. 2006), few publications could be found that explicitly discuss ontologies in the context of classification or ontologies as classification artifacts. One exception is the information sciences; however, discussions are quite limited: Soergel (1999) equates ontology with classification, while Van Rees (2003) attempts to clarify the terms ontology, taxonomy and classification. A search for the term ontology in IS returns numerous results. However, to our knowledge, surprisingly few publications in IS specifically address ontologies in the context of classification. Arguably, given that the nature of classification is that it is an implicit fundamental human endeavor, scholars who use ontologies seem to use the associated classification implicitly without exploring and documenting how they performed the classification.

Computational Ontologies as Classification Artifacts in IS Research

Since the scope of this investigation is classification in IS, the next section provides a summary of relevant research on classification in IS, followed by the results of this experimental investigation.

[5] `Pizza hasTopping some PizzaTopping`.

[6] For instance, asserting that a `MargheritaPizza` is a pizza with at least one kind of `MozzarellaTopping` and at least one kind of `TomatoTopping`, and only these kinds of toppings

Classification in IS Research

Nickerson et al. (2009, 2010, 2013) published several papers on classification and taxonomy development in IS. They identified three approaches, namely inductive, deductive and intuitive. The *inductive* or empirical approach analyzes observations in order to determine dimensions and characteristics in the taxonomy through either rigorous techniques (e.g. cluster analysis) or informal techniques. The *deductive* approach derives a taxonomy through a logical process from a conceptual or theoretical foundation. In the *intuitive* approach the researcher essentially uses his or her perceptions and understanding of the objects to be classified to create a taxonomy (Nickerson et al. 2010). In subsequent work Nickerson et al. develop, apply and validate a method for taxonomy development consisting of two approach branches that reflect the identified empirical-to-conceptual and conceptual-to-empirical approaches (Nickerson et al. 2013).

Nickerson et al. (2013) adopt the term *taxonomy* as the resulting artifact of their method. They furthermore propose a formal definition of a taxonomy, namely: a taxonomy T is a set of n dimensions D_i ($i=1,\ldots, n$), each consisting of k_i ($k_i \geq 2$) mutually exclusive and collectively exhaustive characteristics C_{ij} ($j=1,\ldots,k_i$) such that each object under consideration has one and only one C_{ij} for each D_i, or $T= \{D_i, i=1,\ldots,n|D_i=\{C_{ij}, j=1,\ldots,k_i; k_i\geq 2\}\}$. Nickerson et al. (2013) also specify additional characteristics of taxonomies, namely that taxonomies should be *mutually exclusive* (no object can have two different characteristics in a dimension) and *collectively exhaustive* (each object must have one of the characteristics in a dimension). Together these conditions mean that each object has exactly one of the characteristics in a dimension. In addition, taxonomies should be: 1) concise and parsimonious (contain a limited number of dimensions and characteristics in a dimension); 2) robust (contain enough dimensions and characteristics to clearly differentiate the objects of interest); 3) comprehensive (classify all known objects within the domain under considerations or include all dimensions of objects of interest); 4) extendible (allow for inclusion of additional dimensions and new characteristics within a dimension); and 5) explanatory (contain dimensions and characteristics that do not describe every possible detail of the objects but, rather, provide useful explanations of the nature of the objects under study).

Gerber et al. (2017) extended the work on classification in IS by analyzing research contributions in top journals in IS research that included different types of classification artifacts. They proposed a taxonomy of classification approaches in IS research (Table 1). *Intensional classification (IC)* is a top-down approach dividing a more general class into sub-classes or concepts similar to the conceptual-to-empirical taxonomy development approach of Nickerson et al. *Extensional classification (EC)* is a bottom-up approach analyzing the characteristics of individuals or objects and grouping them into classes from specific to more general based on perceived similarities. This classification approach is similar to the *empirical-to-conceptual* approach of Nickerson et al. (2013).

Table 1: Taxonomy of Classification Approaches (adapted from Gerber et al. (2017))

	Intensional Classification Approach (IC) Top-down, conceptual, deductive.	**Extensional Classification Approach (EC)** Bottom-up, empirical, inductive.
Formal Approach Explicit, formal method usually pre-specified.	**Formal Intensional Classification (FIC)** Explicit deductive method. Artifact: Multi-level or hierarchical taxonomy, e.g. Dewey DC system (Dewey 1876).	**Formal Extensional Classification (FEC)** Explicit inductive method. Artifact: Often a multi-level taxonomy, or quantifiable two-dimensional classification schema e.g. Organizational Taxonomy (McKelvey 1982, 1987).
Intuitive Approach Intuitive, often ad hoc method, vaguely described.	**Intuitive Intensional Classification (IIC)** Implied, intuitive deductive method. Artifact: Typically a folksonomy or metadata tagging schema, or ontologies such as the Gene Ontology (GOC 2015).	**Intuitive Extensional Classification (IEC)** Implied, intuitive inductive method. Artifact: Both a multi-level/hierarchical taxonomy or a multi-dimensional (tabular) classification schema intuitively developed from empirical evidence, e.g. the framework for MIS development projects (Moore 1979).

In addition to the two main classification approaches, Gerber et al. distinguish between *formal* and *intuitive* approaches. A formal classification approach (whether extensional or intensional) is pre-specified and rigorous. An intuitive approach in both the intensional and extensional approaches is evident whenever human intuition is applied. The intuitive approach is ad hoc and relies on human recognition. Gerber et al. found that classification artifacts with less formal specifications than the taxonomies of Nickerson et al. (2013) are accepted and recognized as valid research contributions in IS research, and these are often the result of intuitive approaches (both intensional and extensional).

Guidelines for Computational Ontologies as IS Classification Artifacts

The combined work of Nickerson et al. and Gerber et al. is investigated using the Horridge approach (with Protégé and OWL2) in order to ascertain how these computational ontologies support the taxonomy approaches and artifacts identified in IS. After this experimental analysis of the Horridge approach in the context of classification in IS of Nickerson et al. (2013) and Gerber et al. (2017), guidelines for ontology construction when generating an IS classification artifact are formulated.

- Steps 1 and 2 of the taxonomy method of Nickerson et al. (2013), namely the meta-characteristic and ending conditions, are evident in most ontology engineering methods when stating the purpose, domain and scope of the ontology, as well as establishing the competency questions (Noy et al. 2001, p. 5). Competency questions are a list of questions that a knowledge base based on the ontology should be able to answer (Grüninger and Fox 1995). The ending conditions (step 7 in Nickerson et al. (2013)) are met when the ontology can answer the competency questions.

  Guideline: When constructing an ontology by following the formal classification approaches, the purpose, domain and scope of the ontology should be specified in such a way that the meta-characteristic and ending conditions of the classification artifact are specified according to the relevant step in the method of Nickerson et al. (2013).
- The intensional top-down (conceptual-to-empirical) approach (starting with classes and then defining characteristics) is supported by ontology construction methods, as is evident when specifying a hierarchy of named pizza classes from the menu such as `SohoPizza` (Horridge 2011, p. 48).

  Guideline: When constructing an ontology following any intensional approach, whether formal or intuitive, the specification of named classes and a named class hierarchy with the defining characteristics using object properties is the starting point, and subsequent refinement could be done, asserting further characteristics of the identified classes and using the reasoner to check the classification hierarchy.
- Both the formal and intuitive extensional bottom-up (empirical-to-conceptual) approaches are supported by the ontology construction method. These approaches start by identifying common characteristics that are then grouped to identify more general classes, and within the Horridge approach, this approach is identifiable when refinement of the pizza ontology is done by modeling characteristics that are unique to certain kinds of pizzas. For example, vegetarian pizzas are pizzas without meat or cheese toppings or a `FourCheesePizza` has four or more cheese toppings (Horridge 2011, p. 60,75). A typical construct could thus use unnamed or anonymous classes as described by Horridge (2011, p. 38), namely the class of individuals that `hasCharacteristic` a specific characteristic (similar to the class of individuals that has at least one `hasTopping` relationship to an individual that is a member of the class `MozzarellaTopping`. Ontologies have been used for such modeling in other applications, such as biological taxonomy (Gerber et al. 2014; Gerber, Morar, et al. 2017). In addition, the domain of *ontology learning* supports formal extensional approaches and essentially deals with various systematic methods to identify classes based on the exploration of characteristics (Buitelaar et al. 2005; Maedche and Staab 2004).

  Guideline: When constructing an ontology following any extensional approach, the initial classes defined should be *characteristics* with object properties using these characteristics using unnamed or anonymous classes. Reasoning could be used to assist with the generalization and establishment of the class hierarchy.
- It is possible to adhere to the strict definition of a taxonomy by Nickerson et al. (2013) in an OWL ontology, since mutually exclusive and collectively exhaustive characteristics could be asserted with disjoint and covering axioms (Horridge 2011, p. 71). Versions of less strict classification artifacts such as the classification artifacts identified by Gerber et al. (2017) could therefore also be represented with an ontology. A classification artifact that is not collectively exhaustive or exclusive (such as in a folksonomy) will have no disjoint or covering axioms and with the open world assumption of computational ontologies, the definition of such a folksonomy or tagging schema is adhered to.

  Examples of ontology-based classification artifacts are:

  - A multi-level or hierarchical taxonomy such as when used to formalize a biological taxonomy (Franz and Thau 2010; Gerber et al. 2014). In such a case the hierarchy is mostly reflected by the subsumption relationships or the subclass/superclass in the computational ontology or to refer back to Horridge, the hierarchy of named pizza classes (Horridge 2011, p. 48).

- A two- or multi-dimensional classification schema such as the enterprise ontology (Uschold et al. 1998). In these cases the characteristics are the dimensions modeled in the computational ontology through relations using object properties. An example of this modeling is discussed in Horridge, when referring to multiple sets of necessary and sufficient conditions where each set asserts a dimension (Horridge 2011, p. 96).
- A tagging schema or folksonomy such as the gene ontology (Botstein et al. 2000; GOC 2015), which contains a list of terms or a vocabulary that is used as meta-data and to tag information objects.

Guideline: When constructing an ontology the nature of the resulting artifact should be considered and specified as requirements, e.g. whether the classification should be exhaustive and covering, or open and multi-dimensional. These artifact requirements will also be informed by the original competency questions, and these requirements should result in additional assertions in the ontology, e.g. asserting disjointness or covering axioms.

- In addition, our experimental analysis confirmed that the additional requirements for taxonomies of Nickerson et al. (2013) could be accommodated and an additional advantage is the support for these requirements offered by the standard reasoning services.

  Guidelines: Similar to the guideline above, each of the additional requirements of the classification artifact should be regarded as a requirement for the ontology and the reasoning services should support these requirements: 1) concise and parsimonious: an OWL ontology could be specified to contain a limited number of dimensions and characteristics and standard reasoning services could be used for additional classification in the inferred taxonomy[7]; 2) robust: the reasoning services could be used to ensure that the dimensions and characteristics are sufficiently specified so that classes or individuals are classified correctly and uniquely where required; 3) comprehensive: reasoning services could be used to ensure all known individuals are classified by testing on actual observations; 4) extendible: additional dimensions and classes could be added, and the reasoning could be used to ensure that the ontology remains consistent and satisfiable; and 5) explanatory: ontology reasoners (e.g. as available in Protégé) include explanations for inferences made using the logic basis of the ontology assertions.

- As is evident in previous findings, the standard reasoning services such as included in Protégé provide additional advantages for developing classification artifacts, namely that implicit consequences could be inferred (i.e. computing the inferred hierarchy of *CheesyPizzas* and *VegetarianPizzas* from the named pizza hierarchy (Horridge 2011, p. 67)). The reasoning is thus a tool to assist with the quality of the classification artifact by ensuring consistency and satisfiability, but also ensuring that inferred consequences are correct and that the ontology is specified sufficiently so that inferences that should hold, actually do hold (e.g. making sure all pizzas that should be classified as vegetarian pizzas are classified as such).

  Guideline: Using the available reasoning services, the classification ontology should be verified for consistency and satisfiability, as well as unwanted consequences that indicate incorrect assertions and thus misclassification.

In summary, the experimental investigation indicated that the core activities as specified in ontology construction methodologies directly support the identified IS classification approaches and artifact requirements. A distinction is that the ontology construction approach includes both the top-down and bottom-up approaches for building an ontology, arguably because the environment assists an ontology engineer with refining the ontology through applying both approaches.

Conclusion

This work is concerned with the question of how computational ontologies with their associated construction approaches and technologies (such as reasoners) support classification in IS research. Computational ontologies, owing to their set-theoretical semantics, are particularly suitable for

[7] Refer to Horridge (2011), p. 67

classification functions. The work is anchored in an investigation into classification, specifically the classification approaches and contribution artifacts identified and acknowledged in IS research.

The current work on classification in IS is extended by indicating how computational ontologies and associated technologies, which experienced significant adoption in the field of computing, could be used to assist with the quality and rigor of classification approaches and artifacts within IS specifically. We found that the core ontology construction approaches align with IS classification approaches, and that ontologies allow for the assertion of the identified and necessary restrictions used to ensure that classification artifacts meet the requirements such as stated by Nickerson et al. (2013). In addition, the standard reasoning services that support logic-based ontologies provide several additional advantages, such as inferring implicit consequences, ensuring the ontology is consistent and satisfiable, as well as validating classifications and avoiding misclassifications. The results of this experimental investigation assisted with providing a set of guidelines that could be used to construct an ontology as a contribution that represents any of the classification approaches in IS research. Given the numerous classification artifacts that were identified as meaningful contributions in the top IS journals, our research results could assist scholars developing such classification contributions. Further research could augment the existing approaches identified in IS research by integrating ontology construction methods.

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