ConceptOnto: An upper ontology based on Conceptnet

Erfan Najmi*, Khayyam Hashmi*, Zaki Malik*, Abdelmounaam Rezgui† and Habib Ullah Khan‡
*Computer Science Department
Wayne State University, Detroit, Michigan 48202
Email: {erfan, khayyam, zaki}@wayne.edu
†Department of Computer Science & Engineering,
New Mexico Tech, Socorro, New Mexico 87801
Email: rezgui@cs.nmt.edu
‡epartment of Accounting & Information Systems,
Qatar University, Doha, Qatar 2713
Email: habib.khan@qu.edu.qa

***Abstract*—The exponential growth of information has prompted the introduction of new technologies such as Semantic Web and Common Sense knowledge bases. To connect the different knowledge presentations together is a primary requirement, and ontologies are central we need for this transformation. In this paper we introduce ConceptOnto which is an ontology based on the ConceptNet knowledge base with extension of some of the other properties in some of the more acclaimed upper ontologies. Our goal in the creation of ConceptOnto is readability for humans, and maximizing the functionality while saving the generality of the ontology.**

I. Introduction

In the beginning, the goal of World Wide Web was creating the most comfortable presentation of information similar to books and catalogs. This approach was later followed by number of technologies, such as HTML and CSS, which made the transition of information to human friendly presentation possible. The exponential expansion of World Wide Web introduced a new predicament to extraction of information from the Web. The advancement of search engines such as Yahoo at the time was a sign of this need. Overtime, researchers found out the main issue with the current form of the Web is the lack of understanding on part of machines on “common sense and knowledge” of humans. There have been two general approaches to solve this problem. One short term solution has been to use different algorithms on information retrieval and machine learning to retrieve the necessary data via a fringe understanding of information for machines. On the other hand, the conversion of information to a bridge format which is both understandable for machines and humans is a long term approach which has been chosen by many of the researchers in the field. Semantic Web (SW) is a general term used for many of technologies have been created for this purpose. The key stone for these technologies in this regard have been RDF and OWL for representing information.

The Semantic Web (SW) while comprehensive, needs a deep understanding of human common sense knowledge to understand basic information which seems primitive for most humans. As the base of human communication is relations between concepts, the first step to form this understanding is to create an ontology which maps basic human relations to different concepts while understanding some basic requirements of those relations. The field of Common sense conversion and common sense knowledge bases follows different directions to map the relations and common knowledge to create the datasets. Some works follow the manual information gathering approaches such as asking for data from users, and some other works are more focused on creating instruments to gather required information automatically.

Our analysis of different works in common sense knowledge retrieval and presentation has showed that *ConceptNet* [22] is one of the more comprehensive and extended knowledge bases available for public use. Open Mind Common Sense knowledge-base was founded in 1999 based on simple information gathering approach from normal Web users to generate simple triples with over 30 basic relations. Later on, this work was expanded by the addition of *WordNet* and *Wikipedia*. The generality of the presented knowledge, and the simplicity of the relations and the information makes *ConceptNet* a formidable data-set for generation and extraction of relations.

In this paper we introduce the process and steps of creation of *ConceptOnto* to map the mentioned relations to their equivalent in OWL. The relations are based on the default relations of *ConceptNet* and addition of some equal or useful relations which we consider necessary for an upper ontology with the focus on common sense. The ontology in OWL format is available for general use on our Web site [1]. In *ConceptOnto* our focus is readability for humans, maximizing the functionality while saving the generality of the ontology. Our goal in here is to present a through explanation of concepts and terms in our ontology so a general user can start implementing and using this ontology to create new SW data representations as needed. Throughout this presentation we have tried to consider the major points, however, we encourage and welcome any suggestion to improve the ontology.

The rest of this paper is organized as follows. First, we explain some of the terms used in this paper which need

[1] http://score.cs.wayne.edu/ConceptOnto.owl

978-1-4799-7100-8/14/$31.00 ©2014 IEEE

explicit explanation or needs further description based on the context. In Section III we survey and analyze some of the works both in upper ontology creation and in common sense knowledge bases. In Section IV we describe the process and details of *ConceptOnto*. Section V presents some of the fields which we believe can benefit from our work and finally Section VI shows our future steps and follow up with *ConceptOnto*.

II. Term Definition

In different sections of this work there are a few concepts which need clarification. In the following we describe some of the terms which we believe are more helpful to follow the process and the logic behind parts of the process.

- Open World Logic: In the context of common sense knowledge, open world logic means that every statement can be true unless the opposite is known as a fact. For example unless we specify that the location kitchen cannot be the same location as garage and car is in garage, then the reasoner cannot point out that the car is not in kitchen.
- Common Sense Knowledge Base: Representation of the knowledge that most people generally possess, in a way understandable for intelligence programs which can use natural language or make inference about the world.
- Transitive Relation: A relation between two items is transitive when we can conclude that if a is connected to b with this relation, and b is connected to c, then a is connected to c. For example "table isLocatedNear chair", and "chair isLocatedNear TV", then we can conclude that "table isLocatedNear TV".
  $\forall a, b, c \in X : (aRb, bRc) \Rightarrow aRc$
- Symmetric Relation: A symmetric relation means that this relation holds for both sides, if a related to b, then b is also related to a. For example "abnormal isSimilarTo exceptional", then we can conclude "exceptional isSimilarTo abnormal".
  $\forall a, b \in X : aRb \Rightarrow bRa$
- Reflexive Relation: A reflexive relation means that any item with this relation is related to itself. For example "bird isRelatedTo bird". While on the first look many of the relations, such as isRelatedTo in this case, do not make sense as a reflexive relation, we can see in multiple real world scenarios that defining them as reflexive increases the functionality and usability of our ontology. To clarify this point consider the triple "Bird isRelatedTo Bird". Using this instance in a set of items we can see the relation of two instance of birds, such as peacock and duck compared other animals or other items.

III. Background

As mentioned previously to map common sense to a logic based computer comprehensible format we need two tools. As such, we can divide the related work to this approach to two portions. One part is the works related to *ConceptNet*, creating a common sense knowledge base using different methods. And the second part is the works on defining relations and creating upper ontologies. The other field of work which worths mentioning, but as there hasn't been as many works in it we decided to not create a separate subsection for it, is the tools which has been used to create any of the works we mention in the following. These tools have been created to extract, gather and organize information from different resources. Each of these tools generally works with specific kind of resource. For example *Reverb* [13] is focused on extracting information from web pages, *Pellet* [33] is a reasoner which can be used in Java or in softwares such as *Protege* [31]. *Protege* is a tool which provides the users with necessary instruments to create, understand and analyze ontologies and other SW resources.

A. Common Sense Knowledge Bases

The use of information gathering in the logic based approach, specifically for computers, can be traced to "Advice Taker", a theoretical system introduced in 1963 in the book "Programs with common sense" [26]. The main goal of this project was to create a platform which led the computers learn and reason from their experiences, similar to humans.

Currently, the oldest active work in information gathering from common sense is Cyc [21]. While *Cyc* converted to commercialized product in 1994, there are free versions specifically created for researchers in *OpenCyc* and *ResearchCyc*. *ResearchCyc* provides access to the full *Cyc* knowledge-base under *ResearchCyc* licence. This version has more than 500000 concepts, nearly 5000000 facts and rules (called assertions in *Cyc* context) and more than 26000 relations. This release enables users to use *CycL*, the language generated for use of *Cyc*, and API to create any required application. Also an ontology exporter is available to export specified portions of the knowledge base to OWL. On the other hand, *OpenCyc*, which is freely available to everyone, consists of more than 239000 terms and 2000000 concepts which is last updated in 2012.

Another significant work which functions as a bridge between dictionaries, encyclopedias and common sense knowledge is *WordNet* [14]. *WordNet*, started in 1985, is currently in version 3.1. Also the 3.0 version is available in RDF which contains more than 155000 words. *WordNet*, other than providing synonyms, antonyms, meronym and holonym, provides different senses for each word, creating a hyperlinked network of words. Considering that *WordNet* does not support different languages, there have been works on a similar platform for European languages under *EuroWordNet* [43].

A similar work to *WordNet* but comparably newer is *BabelNet* [30]. *BabelNet* replaces *WordNet's* senses and synsets with Babel synset. BabelNet's latest release as of April 2014 is 2.0.1. There are a few points which makes BabelNet special compare to similar works. First, BabelNet consists of 50 languages (in October 2013). Second, it natively supports Lemon/RDF encodings. And finally it provides 7.7 millions images interlinked with the concepts in the data-set.

ThoughtTreasure [28] was another work to gather common sense knowledge. The work on this approach started in 1993 and the support stopped in 2000 after the founder moved to IBM research to be part of the group which later developed Watson. Final release of *ThoughtTreasure* has more than 27000 concepts and 51000 assertions in English and French.

A specific case of common sense knowledge base is *YAGO* [41] started in 2008. While gathering information from *Wikepedia*, *WordNet* and *Geonames* it has gathered more than 10 millions entities, 120 millions facts and 350000 classes in its current version (*YAGO2*) released in 2012. This knowledge base has a comprehensive data on IsA taxonomy and schema which has been used as one of data sources for IBM Watson.

A different approach to information presentation is used in *SenticNet* [11] by providing pleasantness, attention, aptitude and polarity of phrases in [-1.1] range. The latest version of this knowledge-base, version 3.00, is currently in beta. We summarized the contribution and works in some of the knowledge bases specifically in common sense field in Table I.

B. *Upper and more common ontologies*

An upper ontology is an ontology which describes different concepts in a general sense suitable for use in multiple fields. While the approach to upper ontologies has been controversial at best [15], the need for an upper relationship management as backbone for any other ontologies and information presentation is generally acceptable and understandable. For this purpose, multiple organizations and research groups have generated different upper ontologies for different purposes. In the following, we shortly describe some of these works.

The *Basic Formal Ontology (BFO)* [5] is a small Upper ontology specifically designed for information retrieval, analysis and integration to scientific and other domains. The important consideration of this ontology is the lack of focus on physical and specific entities which makes it possible for the ontology to be used in many different fields. Majority of current practices of this ontology can be found in biomedical and security ontologies. An example application of *BFO* can be seen in the Ontology for Biomedical Investigations (OBI) [10].

Open Robots Common Sense Ontology (ORO) [20] is an ontology created for use in AI and robotics with focus on properties. *ORO* has been implemented in Java and as such has dependency to Java Virtual Machine, Jena RDF triple store, and Pellet for reasoning. The ontology has been maintained from 2008 to 2011. Considering the approach of this work, it is noteworthy that there are multiple parallel relations as data properties with binary range to create better environment for robotic data presentation.

Simple Knowledge Organization System (SKOS) [27] is the W3 recommended approach to provide an easier migration path to convert data to RDF and other SW formats. It has been specifically created for conversion of thesauri, taxonomies, classification schemas and subject heading lists. Using the *SKOS* primer we can identify 5 main components of *SKOS* definition. First, “Concept” to present any unit of thought. Second, “Labels” to add description to concepts. To present the facts about concepts, a different component is used, which has logical difference with labels, called “Documentary Notes”. To describe and understand concepts further, “Semantic Relations” is used to connect the concepts and clarify their meaning. Finally, “Concept Schemas” is used to present the used vocabulary to describe the concepts.

One of the suggested ontologies by W3 is *Dublin Core* [44]. *Dublin Core* focuses on enabling ubiquitous access to cultural and scientific resources through galleries, libraries, archives and museums (GLAM). This goal is achieved by providing specific properties and classes suitable for this need such as language, license and publisher.

Talking about most acclaimed and used ontologies, *Friend Of A Friend (FOAF)* [9] has been a dominant ontology to present people and organizations since the beginning of the SW movement. The goal of *FOAF* is to provide a standard vocabulary for generating and presenting personal and organizational information such as name, address, email address in the SW format as part of *WebID* [40] standards.

To name some of the other ontologies widely used in different context, we mention *SIOC (Socially Interconnected Online Communities)* to complement *FOAF* to describe the products of forums, blogs mailing lists and wikis; *GO (GoodRelations)* [17] to describe products sold online; *Music Ontology* [36] to describe information related to music industry (not the music itself).

While most mentioned works focus on general approach to infrastructural path to entity representation, there has been different tries to map human emotions to an ontology. The two major works in this field are *HEO (Human Emotion Ontology)* [16] and *Smiley ontology* [35]. *HEO* mostly focuses on emotions and emotion representations while Smiley generally presents ways to express emoticons by different metrics and descriptions.

Discussing upper and generally used ontologies, it is important to mention *Schema.org* and the general acceptance of its different ontologies in SW community. Unfortunately the OWL version of the ontology on their web site is old and has not been maintained, but TopQuadrant has generated a new and reasoned version of the ontology in OWL format for public use. The ontology main classes are action (any action performed by and agent), creative work (any creative work in any field), data type (including basic data types such as integer), event (any event in any field), intangible (a class to cover many intangible “things” such as quantities), medical entity (any entity related to medical field such as tests studies and devices), organization (covering different organizations), person (covering any person, dead, alive or even fictional), place (entities that have fixed, physical extension) and product (anything which is made available for sale).

IV. Methodology

Our ontology consists of two main parts which we describe separately in the next two sections. In the first section we introduce and define the classes implemented in our ontology and some of the uses in different relations. The second section focuses on properties in *ConcpetOnto*. We define the different properties, their relation with each other and corresponding relation properties.

A. *Classes*

To identify base classes to be implemented in our ontology (considering that the goal is to create a general purpose relation ontology) we returned to the basic entities of *ConceptNet*. These classes consist of four general purpose items. We provide a brief explanation of these classes in the following.

Approach	Year Founded	Year Stopped	Data	Available to download	Notes
MindPixel [2]	2000	2005	1.4M	no	
Evi	2005	2012	300M	no, app available	Bought by Amazon in 2012. Formerly True Knowlledge
Probase [45]			2.7M	no	Belongs to Microsoft, for internal use
ThoughtTreasure [28]	1993	2000	27K concepts, 51K assertions	no	
NELL [12]	2010		50M	yes	Never Ending Language Learning (NELL)
Open Information Extraction [6]			15M	yes	From Clue Web 99 data-set
Freebase [8]	2007		2.5B+ facts, 43M+ topics	yes	RDF available. Google bought in 2010
UMBEL [3]	2008	2012	25K (based on their web site)	yes	Subset of OpenCyc
Yago [41]	2008, Yago2 2012		10M entities, 120M facts, 350K classes	yes	
WordNet	1985		155K words in V3.00	yes	
BabelNet	2012		9M synsets, 50M word senses	yes	
ResearchCyc	2012		50K concepts, 5M facts	yes	
SenticNet	2010			yes	On Sentiment Analysis
OMCS [38]	1999		1M+	no	Used in Conceptnet

TABLE I. WORKS IN COMMON SENSE KNOWLEDGE RETRIEVAL

Noun Phrase (NP) is by far the most common entity in *ConceptNet*. These phrases normally consist of one or more main noun as the root and one or more other parts to clarify the noun. For example for the relation isDefinedAs, for any triple, the object and subject are *NP*.

Verb Phrase (VP) is any phrase which has a verb as its root. These verbs can be precedented or succeeded by any other word. An example of a *VP* is the property “isCapableOf” with the triple “bike isCapableOf moving_forward”, moving_forward is a verb phrase with the root of the verb moving followed by the adjective “Forward”.

Adjective Phrase (AP) is the general term uses specifically in range and domain of properties such as “hasProperty”. Any *AP* can consist of a set of words which in turn can have multiple adjective, noun or even verbs. For example in triple “bike hasProperty common_In_Asia”, common_In_Asia while starts with an adjective, follows by a noun to complete the concept.

Terms are the last class of entities in *ConceptNet*. Terms are general phrases used in “isDerivedFrom” or “isTranslationOf” which shows the relation between two phrases when one derives from the other one or the phrases are equal in different languages. For example in the triple “begin isDerivedFrom start” subject and object are verbs while in “earth_science isDerivedFrom earth” the object is a NP and the subject is a noun. This generality of concept in Terms make all the other classes subclass of this class.

To compare classes in *ConceptNet* with classes in *WordNet* (as an example of a similar work) we like to mention a few key differences. First, the classes in Conceptnet are comparably very general. For example for NP, any phrase with a noun root belongs to this class. Second, in works like WordNet there is a high focus on linguistic analysis of terms, while considering that in Conceptnet the main focus in on common sense, the relations are based on common sense which can have ambiguities meaning depend on general user perspectives and understanding of different concepts and relations. Compare to classes in *SKOS* [27] , *SKOS* is focused on units of thoughts and concepts (using equally in SKOS) while completely ignore any linguistics of concepts. Another generally used upper ontology to discuss is BFO [5]. Classes in BFO are divided by their temporal identities. If a concept is independent of temporal properties, then it classifies as continuant. On the other hand if a concept is dependant to a temporal variable it classifies as occurrent. In our ontology there is no focus to identity of concepts time wise. GFO [18] is another upper level ontology with focus on sets as its entities. It separates entities to two, items belonging to sets (based on ZFC [7] set definition) and items which do not belong to sets. *Relation Ontology (RO)* [39] is possibly the closest ontology to our approach regarding the properties, but on the subject of classes, the focus is mainly on sets and synonyms. Also as this ontology still evolving, in the newer versions there is an obsolete class for the classes that has been replaced. *UMBEL* [3] has a different approach to class definition. While separating concept as a unit of thought, it defines superclass which consists of mostly disjoint classes for other entities such as people, food and diseases. This through classification makes it easier to introduce new concepts, but most of these classes can be used in simple triples such as “Pizza isA food” with further explanation.

B. Properties

In this paper we use properties in place of relationships as been used in SW context. While the majority of the properties are directly dictated from ConceptNet relations, We make several modifications to improve the functionality and mobility of the ontology for making it compatible to open world scenarios. We have to remember that properties in ConceptNet are not definite as in the general ontology relations. Even if any of the properties are not true in a logical sense, it is possible it “makes sense” which is the definition of common sense and the main point of difference to any other information gathering approach. Another point to consider toward different relations is the cultural difference between different languages in ConceptNet. To clarify this point consider the property “desires” in the following triple which is translation of Korean: “cockroach desires slippers” which in English does not make sense as slippers are not the desire of cockroach.

The first major modification concerns naming. As the general approach to property creation in ontologies, we try to modify the relations by adding the two keywords “is” and “has” based on objective or subjective meaning of relations. This naming methodology defines the difference between having a specific property versus the entity resides in another entity. This is why if a property begins with “is” the reverse begins with "has" and vice versa. While we haven't found the use of "is" and "has" in this extent in similar works, this methodology is suggested in main OWL tutorials [19].

The second change is the use of reverse properties. Considering the open world logic, generating reverse properties, while *ConceptNet* originally does not include most of them, let us analyze more possible scenarios of events and concepts. Another effect of reverse properties is the generalization benefit. The data from *ConceptNet* is provided from general users perspective toward knowledge, so the information are concerns with the general approach to common sense which in most cases considers reverse relation an obvious logical conclusion. On the other hand, in SW logic, unless you directly point to the fact to what reverse function means and if is true or not, we cannot indirectly include the reverse functions. It is important to note the same logic for the transitive, symmetric and reflexive properties. Finally, there are only three properties which have subproperty/superproperty relation. The properties LastSubeventOf and FirstSubeventOf are sub properties of SubeventOf. In the context of OWL properties this means that every instance of the two mentioned properties is an instance of SubeventOF.

An important property we need explicit attention to is the "IsA" relationship. RDFS:SubclassOf has the same specification and meaning as IsA in general case. We believe implementing IsA in the ontology has two main benefits. First the domain and range of IsA relation in *ConceptNet* is NP. While the RDFS:SubclassOf does not have this limitation, in general we believe the functionality is used for noun phrases more than any other class of words. The second benefit of an explicit IsA property is better readability for human eyes which makes the presentation of the information easier in different cases. For the same case in RO [39] ontology the preference has been on using RDFS:SubclassOf instead of implementing IsA.

After analyzing different data from both *ConceptNet*, and other knowledge bases and ontologies we decide to add some other properties which makes the conversion and addition of different sources easier. The first set of properties is in regard to creation and demise of any entity. This addition which in both cases are data properties (different from object properties which are native of *ConceptNet*) have a range of literal which is dates in this case. It is important to emphasize that these properties can be used for humans, in the concept of born and death, buildings, in the concept of being built and demolished, or even cities, in the concept of the first settlers to the last citizens. While we can create sub-properties for each of these cases, we believe while having one relation for all simplifies things, it also creates a unified way to present different concepts, while they are differentiable by their other relations such as IsA properties. Another addition to *ConceptOnto* is existential relation between concepts. These properties are modified version of properties implemented in *General Formal Ontology (GFO)* [18] as depend_on and necessary_for. We have changed the names to isDependOn and isNecessaryFor and changed the domain and range of it from Item in *GFO* to Term in *ConceptOnto*.

As mentioned previously, RO is the closest ontology to our work mainly because of the closeness of properties implemented. To consider the similarities of the two ontologies we use the EquivalantObjectProperties to define the equivalency of the properties such as isDerivedFrom from our ontology to derived_from in RO to unify and make the process of mapping different ontology and resources faster and easier.

Finally to check, expand and extract implicit relations in *ConceptOnto* we tried two different reasoners to find the best addition to our work. After through analyze of FaCT++ [42] and HermiT [37], we used HermiT to make the final modifications to our ontology such as using the equivalent relations for expanding the inverse relations.

Table II shows the properties implemented in *ConceptOnto*. The first column shows the name of the relation as in the ontology. Second column shows the specific properties of the relation which consist of Transitive, Symmetric and Reflexive. If the inverse of the relation has also been implemented in the ontology, its name can be found in the third column of the table. The fourth column is the original name of the relation as available in *ConceptNet*. If the relation has an equivalent in one of the discussed ontologies in previous sections, its name is available in the fifth column. And finally, the sixth column of the table shows the domain and range of the relation of *ConceptOnto*. For example, the first row of the table is describing the property isSimilarTo which is both transitive and symmetric. This property does not have an inverse and originally presented as SimilarTo in *ConceptNet*. An equivalent of this property is presented in *Relation Ontology (RO)* as SimilarTo and finally the property goes from Noun Phrase (as its domain) to Noun Phrase (as its range).

V. USE CASES

While the main benefit of a general use upper ontology is to represent information, this approach can be useful in many different fields of research and practical use. One of the main issues in any of the fields related to information retrieval is the accessibility of information both computationally and time wise. A field which we believe can have immense benefit from an easier data representation is "Question Answering". As we presented an approach to use RDF triples in this field [29], we have discussed that converting a question to a triple useable in SPARQL [34] is far less complicated than find the information online in any of the current SW repositories, considering the size of the current knowledge in required format. We believe the corner stone to our approach and similar approaches [23] [25] [24] in this field is a thorough ontology which presents the possibility to convert different available and to be available knowledge bases to RDF.

Another research area which has gathered a lot of attention in the past few years is sentiment analysis. While there have been a few work specifically focused on Sentiment Analysis (as mentioned in Section III) but on a higher perspective, bridging the gap between human understanding of emotions compared to machine understanding, is a more sophisticated topic which needs further research. The presentation of emotions in SW formats can be a good start in this direction. To do so, new ontologies with deeper relations to present different situations and scenarios can help this cause. While we do not claim that *ConceptOnto*, at this state, is providing the tools to present emotions, we believe it provides the necessary tools to present different emotions presentation in form of words.

Property	Properties	Inverse	Original Property	Equivalent	Domain → Range
isSimilarTo	T, S		SimilarTo	RO:similarTo	NP → NP
isAtLocation			AtLocation		NP → NP
isCapableOf			CapableOf		NP → VP
isCreatedBy			CreatedBy		VP → NP
isDefinedAs			DefinedAs		
isDerivedFrom		isDerivedInto	DerivedFrom	RO:derives_from	
isLocatedNear	T, S, R		LocateedNear		NP → NP
isMadeOf			MadeOf		NP → NP
isPartOf	T	hasPart	PartOf	RO:part_of	
hasPrerequisite		isPrerequisite			NP,VP → VP,NP
hasProperty		isPropertyOf	HasProperty		NP → AP
causes		causedBy	Causes	RO:causes	
reveivesAction		givesAction	ReceivesAction		NP → VP
isTranslationOf	T, S				Term → Term
hasSubevent		isSubeventOf	HasSubevent		VP → NP,VP
hasFirstSubevent		isFirstSubeventOf	HasFirstSubevent		VP → NP,VP
hasLastSubevent		isLastSubeventOf	HasLastSubevent		
hasSynonym	T, S				Term → Term
hasAntonym	S		Antonym		Term → Term
isA			isA		NP → NP
isMotivatedByGoal			MotivatedByGoal		
desires			Desires		
hasA			HasA		NP → NP
isRelatedTo	T, R		RelatedTo		NP → NP
isSymbolOF		hasSymbolOf	SymbolOF		NP → NP
isUSedFor			UsedFor		NP → VP
isDependOn	T	isNecessaryFor		GFO:depend_on	Term → Term
isBornOn					NP → literal
isDestroyedOn					NP → literal

TABLE II. CONCEPTONTO PROPERTIES SPECIFICATION. T: TRANSITIVE, S: SYMMETRIC, R: REFLEXIVE

While in the past few years search engine technologies had many major advances, the real technology behind these engines has stayed the same. Innovations such as *PageRank* [32] from Google has changed the perspective on finding valuable resources on the Web, but finding related contents to user inquiries is still mostly based on content similarities and closeness of concepts together. A major issue with improving the quality of search engines is the nature of information on World Wide Web. In lack of traditional databases, a replacement tool which has the potential to present the information in more machine understandable way is by use of Semantic Web technologies. There are two approaches have been introduced to implement the aforementioned solution. The use of current infrastructure of WWW, use of HTML and similar taggings, has been the chosen approach for works in MicroFormats [1], RDFa [4] and similar approaches. On the other hand, the general transformation of information presentation in SW formats is a harder approach which requires remake of the infrastructure for specific SW technologies. We believe the first step to achieve this goal is to provide an ontology to map general knowledge to SW format. *ConceptOnto*, as an ontology based on common sense which has been created by the purpose of representing general understanding of natural language, can be a useful tool for conversion and retrieval of this information.

VI. CONCLUSION AND FUTURE WORK

In this paper we present our implementation of an upper ontology based on the *ConceptNet* knowledge base relations. We have tried to generalize the relations using the inverse relations and addition of relations of some of the more used ontologies in the field. Also for different classes we used the entity classes of *ConceptNet* which focus on different phrase roots. Another point of focus in our ontology is relation properties such as transitive, symmetric and asymmetric relations.

The base of our ontology in relations implemented in *ConceptNet*. The next step for our work is to convert the data in *ConceptNet* in RDF format. The generality we tried to implement in this ontology provides us with the opportunity to convert any triple based data-set to RDF format. It is expected that the relationships and classes in this ontology may not suffice to cover all the different vocabularies in different domain-specific data-sets, so it is of utmost importance that the ontology be treated as an open source resource and be maintained periodically. Finally, using the result of the newly created knowledge bases to implement the mentioned use cases is another future expansion to our research.

REFERENCES

[1] Microformats. http://microformats.org/.

[2] Mindpixel project. http://www.mindpixel.org, 2005.

[3] Upper mapping and binding exchange layer. http://umbel.org/, 2012.

[4] Ben Adida and Mark Birbeck. Rdfa primer: Bridging the human and data webs. *Retrieved June*, 20:2008, 2008.

[5] Robert Arp and Barry Smith. Function, role, and disposition in basic formal ontology. *Nature Precedings*, 1941(1):1–4, 2008.

[6] Michele Banko, Michael J Cafarella, Stephen Soderland, Matthew Broadhead, and Oren Etzioni. Open information extraction for the web. In *IJCAI*, volume 7, pages 2670–2676, 2007.

[7] Donald W Barnes and John M Mack. Zermelo-fraenkel set theory. In *An Algebraic Introduction to Mathematical Logic*, pages 52–61. Springer, 1975.

[8] Kurt Bollacker, Colin Evans, Praveen Paritosh, Tim Sturge, and Jamie Taylor. Freebase: a collaboratively created graph database for structuring human knowledge. In *Proceedings of the 2008 ACM SIGMOD international conference on Management of data*, pages 1247–1250. ACM, 2008.

[9] Dan Brickley and Libby Miller. Foaf vocabulary specification 0.98. *Namespace Document*, 9, 2012.

[10] Ryan R Brinkman, Mélanie Courtot, Dirk Derom, Jennifer Fostel, Yongqun He, Phillip W Lord, James Malone, Helen E Parkinson, Bjoern

Peters, Philippe Rocca-Serra, et al. Modeling biomedical experimental processes with obi. *J. Biomedical Semantics*, 1(S-1):S7, 2010.

[11] Erik Cambria, Robert Speer, Catherine Havasi, and Amir Hussain. Senticnet: A publicly available semantic resource for opinion mining. *Artificial Intelligence*, pages 14–18, 2010.

[12] Andrew Carlson, Justin Betteridge, Bryan Kisiel, Burr Settles, Estevam R Hruschka Jr, and Tom M Mitchell. Toward an architecture for never-ending language learning. In *AAAI*, 2010.

[13] Anthony Fader, Stephen Soderland, and Oren Etzioni. Identifying relations for open information extraction. In *Proceedings of the Conference on Empirical Methods in Natural Language Processing*, pages 1535–1545. Association for Computational Linguistics, 2011.

[14] Christiane Fellbaum. *WordNet*. Wiley Online Library, 1999.

[15] Luciano Floridi. *The Blackwell guide to the philosophy of computing and information*. John Wiley & Sons, 2008.

[16] Marco Grassi. Developing heo human emotions ontology. In *Biometric ID Management and Multimodal Communication*, pages 244–251. Springer, 2009.

[17] Martin Hepp. Goodrelations: An ontology for describing products and services offers on the web. In *Knowledge Engineering: Practice and Patterns*, pages 329–346. Springer, 2008.

[18] Heinrich Herre, Barbara Heller, Patryk Burek, Robert Hoehndorf, Frank Loebe, and Hannes Michalek. General formal ontology (gfo)–a foundational ontology integrating objects and processes. *Onto-Med Report*, 8, 2006.

[19] Matthew Horridge, Holger Knublauch, Alan Rector, Robert Stevens, and Chris Wroe. A practical guide to building owl ontologies using the protégé-owl plugin and co-ode tools edition 1.0. *University of Manchester*, 2004.

[20] Séverin Lemaignan, Raquel Ros, L Mosenlechner, Rachid Alami, and Michael Beetz. Oro, a knowledge management platform for cognitive architectures in robotics. In *Intelligent Robots and Systems (IROS), 2010 IEEE/RSJ International Conference on*, pages 3548–3553. IEEE, 2010.

[21] Douglas B Lenat, Mayank Prakash, and Mary Shepherd. Cyc: Using common sense knowledge to overcome brittleness and knowledge acquisition bottlenecks. *AI magazine*, 6(4):65, 1985.

[22] Hugo Liu and Push Singh. Conceptneta practical commonsense reasoning tool-kit. *BT technology journal*, 22(4):211–226, 2004.

[23] Vanessa Lopez, Michele Pasin, and Enrico Motta. Aqualog: An ontology-portable question answering system for the semantic web. In *The Semantic Web: Research and Applications*, pages 546–562. Springer, 2005.

[24] Vanessa Lopez, Victoria Uren, Enrico Motta, and Michele Pasin. Aqualog: An ontology-driven question answering system for organizational semantic intranets. *Web Semantics: Science, Services and Agents on the World Wide Web*, 5(2):72–105, 2007.

[25] Gideon S Mann. Fine-grained proper noun ontologies for question answering. In *Proceedings of the 2002 workshop on Building and using semantic networks-Volume 11*, pages 1–7. Association for Computational Linguistics, 2002.

[26] John McCarthy. *Programs with common sense*. Defense Technical Information Center, 1963.

[27] Alistair Miles and Sean Bechhofer. Skos simple knowledge organization system reference. Technical report, Technical report, W3C, 2009.

[28] Erik T Mueller. *Natural language processing with ThoughtTreasure*. Citeseer, 1998.

[29] Erfan Najmi, Khayyam Hashmi, Fayez Khazalah, and Zaki Malik. Intelligent semantic question answering system. In *Cybernetics (CYBCONF), 2013 IEEE International Conference on*, pages 255–260. IEEE, 2013.

[30] Roberto Navigli and Simone Paolo Ponzetto. Babelnet: Building a very large multilingual semantic network. In *Proceedings of the 48th annual meeting of the association for computational linguistics*, pages 216–225. Association for Computational Linguistics, 2010.

[31] Natalya F Noy, Michael Sintek, Stefan Decker, Monica Crubézy, Ray W Fergerson, and Mark A Musen. Creating semantic web contents with protege-2000. *IEEE intelligent systems*, 16(2):60–71, 2001.

[32] Lawrence Page, Sergey Brin, Rajeev Motwani, and Terry Winograd. The pagerank citation ranking: Bringing order to the web. 1999.

[33] Bijan Parsia and Evren Sirin. Pellet: An owl dl reasoner. In *Third International Semantic Web Conference-Poster*, volume 18, 2004.

[34] Eric PrudHommeaux, Andy Seaborne, et al. Sparql query language for rdf. *W3C recommendation*, 15, 2008.

[35] Filip Radulovic and Nikola Milikic. Smiley ontology. In *Proceedings of The 1st International Workshop On Social Networks Interoperability*, 2009.

[36] Yves Raimond, Samer A Abdallah, Mark B Sandler, and Frederick Giasson. The music ontology. In *ISMIR*, pages 417–422. Citeseer, 2007.

[37] Rob Shearer, Boris Motik, and Ian Horrocks. Hermit: A highly-efficient owl reasoner. In *OWLED*, volume 432, 2008.

[38] Push Singh, Thomas Lin, Erik T Mueller, Grace Lim, Travell Perkins, and Wan Li Zhu. Open mind common sense: Knowledge acquisition from the general public. In *On the Move to Meaningful Internet Systems 2002: CoopIS, DOA, and ODBASE*, pages 1223–1237. Springer, 2002.

[39] Barry Smith, Werner Ceusters, Bert Klagges, Jacob Köhler, Anand Kumar, Jane Lomax, Chris Mungall, Fabian Neuhaus, Alan L Rector, and Cornelius Rosse. Relations in biomedical ontologies. *Genome biology*, 6(5):R46, 2005.

[40] Manu Sporny, Toby Inkster, Henry Story, Bruno Harbulot, and Reto Bachmann-Gmür. Webid 1.0: Web identification and discovery. *W3C Editors Draft*, 2011.

[41] Fabian M. Suchanek, Gjergji Kasneci, and Gerhard Weikum. Yago: A Core of Semantic Knowledge. In *16th international World Wide Web conference (WWW 2007)*, New York, NY, USA, 2007. ACM Press.

[42] Dmitry Tsarkov and Ian Horrocks. Fact++ description logic reasoner: System description. In *Automated reasoning*, pages 292–297. Springer, 2006.

[43] Piek Vossen. Introduction to eurowordnet. In *EuroWordNet: A multilingual database with lexical semantic networks*, pages 1–17. Springer, 1998.

[44] Stuart Weibel, John Kunze, Carl Lagoze, and Misha Wolf. Dublin core metadata for resource discovery. *Internet Engineering Task Force RFC*, 2413(222):132, 1998.

[45] Wentao Wu, Hongsong Li, Haixun Wang, and Kenny Q Zhu. Probase: A probabilistic taxonomy for text understanding. In *Proceedings of the 2012 ACM SIGMOD International Conference on Management of Data*, pages 481–492. ACM, 2012.