An OWL Ontology: A Commercial Catalogue Of Adult Products

ICT6005: Semantic Web

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Abstract

Electronic marketplaces have become the industry standard of retail sales. Products and services are traded in a semi-automatic way. Electronic product catalogs provide the basis for offering products on such a marketplace. Efficient use of electronic marketplaces requires effective matchmaking among products and services by potential customers. Matchmaking algorithms are deployed trying to find products that meet the customer's needs as close as possible. To determine which products are suitable enough, dependencies and connections are often needed among products and their intended use. This means that matchmaking has to understand the nature of a product to decide whether reflects the customer’s needs, and it has to be customizable towards the specific needs (Nowakowski & Stuckenschmidt, 2010).

In this paper, the idea of ontology-based matchmaking of products is reviewed. The work done is more profound, with defined classes and sub-classes, their respective object properties, explicit labeling, and product description, achieving a wide variety of connections. Furthermore, more aspects of a shop's activities are explored and connections among them. The final product aims to propose a well-defined end-to-end mapping of services, products, obligations, and ways of communication, a physical store, a digital store, or both may have in the contemporary marketplace.

Keywords

Protégé, Ontology, SPARQL, e-commerce, OWL, e-catalog services

Contents

Introduction

The rapid rise of the World Wide Web aided various sectors in our daily lives, including the need for many companies worldwide to expand their e-commerce operations. The Web has changed the way that businesses run. Over the last few years, online retail platforms have undergone an unprecedented global traffic increase. Statistical studies have shown a 38% increase in the first quarter of 2021, corresponding to $876 billion in global sales, mainly due to COVID-19 (Verdon, 2021). Along with the fact that the retail landscape has transformed thanks to the ongoing digitalization of modern life substantially, it has created imperative needs in terms of thoughtful content organization and browsing support. Following, a literature review with a compilation of previous research and writing on the particular topic is presented, in an attempt of understanding the surrounding areas of e-commerce service system.
E-commerce is the consequence of merging the Business to Customer (B2C) business and business (B2B) transactions commonly used in the market. The power of e-business led to the need for the development of an ontology. The semantics associated with products of an e-shop rich make it a challenging topic for creating an ontology. As ontology's scope is the derivation of meaningful knowledge from information that can convey semantic meanings and be interpreted and understood by machines, ontology is considered crucial in e-commerce as a formalization of e-Catalog.

The development of an e-shop's catalog is based on product classification standards, meaning that the products are grouped/categorized based on their characteristics or some main differences they may have. The Chinese Standardization Research Institute implements general product classification standards based on XML, comparing them with seven different product description standards used in e-commerce scenarios, their complexity, and potential integration problems, but only based on straightforward metrics (Chen, Liang, & Zhang, 2010).

In 2007, a research of a retail ontology that can automatically deduce answers to retail queries based upon the system's general knowledge of online retailing and actual data took place.

Scope of the project

Many scientific articles related with the stages of semantic query based on e-Catalog, including e-Catalog standardization and integration, personalized catalog service research, and e-Catalog ontology design have been published.
Construction e-Catalog is based on product classification standards. The Chinese Standardization Research Institute implements a general product classification standard based on XML (de Bruijn, M., Keller, Lausen, & Scicluna, 2008). Some of these XML standards are compared by Li (Casasola, 1998), who discusses seven different product description standards used in e-commerce scenarios, their complexity, and potential integration problems, but only on the basis of straightforward metrics. International product classification standards — UNSPSC, eCl@ss, RosettaNet, EGAS, NCS, etc. — established a comprehensive classification level (Chen, Ho, & Yang, 2006) (Doring & KieBling, 2006). These classification standards are different

from each other in structure and content and lack semantic service ability. Presents a practical model for eCl@ss and touches upon the practical issues for classification schemes.

For the scope of this course, a simple-structured ontology is constructed and populated in Protégé environment. Based on knowledge and research, the decisions about which relationships and properties could be applied will be taken. Based on the conception of the Web as an Open World, where new information could come to light at any time, inferred information, as depicted by the inferred hierarchy, is being presented. The project's goal is an inferred hierarchy, computed by the reasoner, that differs from the asserted one because new knowledge is inferred. These new connections provide the ability to prove the consistency of that information or to convert verifiable information to unequivocal. The main concern of this project is to make a well-structured ontology, after a cautious definition of the following mentioning components of the sex shop ontology as follows:

- Determine the domain (e-shop products)
- Define classes & class hierarchy
- Define properties of these classes
- Create instances (i.e., individuals)

Since all data are pre-linked in the ontology, efficient information retrieval via the RDF query language SPARQL is being conducted in the end. The appraisal of the connected data structure will be based upon the capacity to precisely act for the data self-assuredly and the capacity to create the specified inductions.

Materials and Methods

The goal is to develop an e-commerce ontology, particularly of a sex shop and its parts, including the third parties, employees, services, manufacturers, and shop obligations. The sheer size of the e-commerce sector and the complex relationships between the classes would result in a humongous schema; hence, it was decided that the complexity should be lowered, and only the most elementary classes, which represent core concepts in the e-commerce field, were included. The characteristics of the asserted hierarchy are presented in the sections below:

Classes & Subclasses

The design of the classes and subclasses of the sex shop domain was based on the knowledge drawn from external web sources (ErosArt, 2021). The class Thing, the root class representing the set containing all individuals, describes the domain at hand.
Subclasses of Thing in the first level of the class hierarchy are presented below, along with a short description:

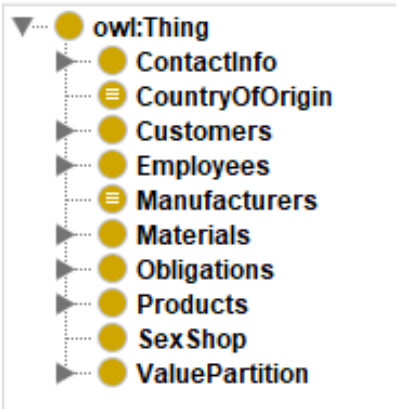

Figure 1: First level classes

- ContactInfo is a class containing the physical and electronic shop contact info.
- CountryOfOrigin a class containing individuals, indicating the products' country of origin.
- Customers is a class containing either retail customers or businesses that buy products from the sex shop.
- Employees is a class containing as individuals the employees' names and three subclasses, partitioning their wage.
- Manufacturers is a class containing individuals, which are the products' manufacturers.
- Materials is a class containing classes and subclasses of the products' materials.
- Obligations is a class containing the primary shop obligations.
- Products is a class containing all the products of the shop and the relevant subclasses (Deals and ProductCategories).
- Sexshop is a class containing the name of the shop as an individual.
- ValuePartition is a class containing the primary subclasses which are used for partitioning other classes.

Following are the second level classes of each of the mentioned classes.

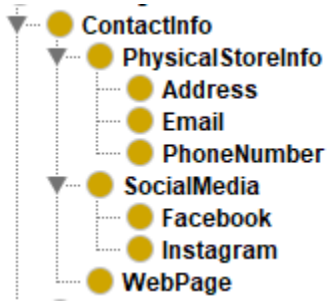

Figure 2: ContactInfo Subclasses

The PhysicalStoreInfo contains the information for the physical store. The Address, Email, and PhoneNumber are classes containing individuals as information of each class.
The SocialMedia contains the information for social network information. Facebook and Instagram classes contain individuals as the information of each class.
The WebPage class contains the information for the e-shop site. It contains individuals as the information for this class.

The classes are designed to accept more individuals as information for each class in the future.

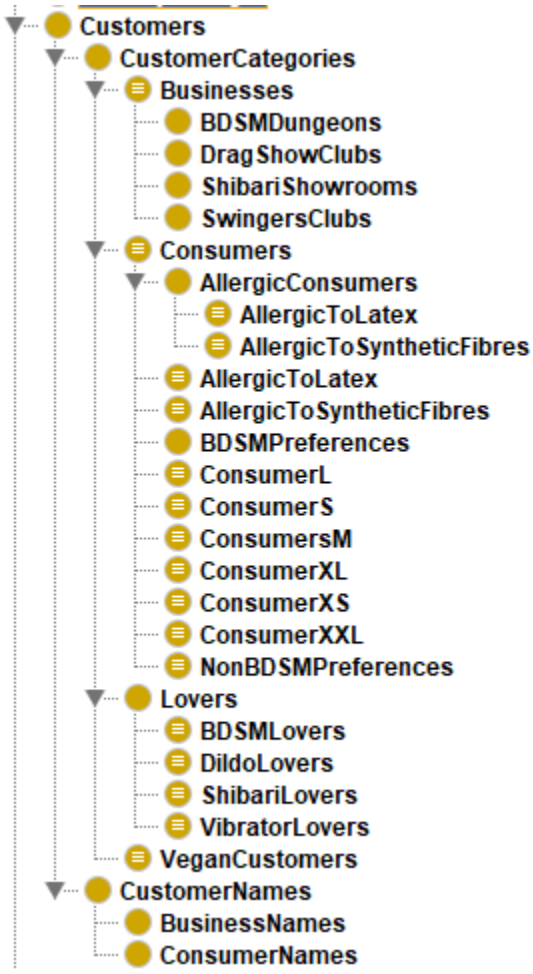

Figure 3: Customers Subclasses

The CustomerCategories is one of the two main subclasses of the customers class. It contains the main subclasses of the customers' types. These are described in the table below:

Businesses: Contains subclasses with business profiles, affected mainly by the preferences of the customers. Each subclass has individuals with company names
Consumers: Contains subclasses of retail customer profiles. Each subclass is affected by some customer preferences, specific possible allergies a customer may have, or the size of products the customer prefers
Lovers: Contains subclasses of retail customer profiles. Each subclass is affected by some customer preferences
VeganCustomers: A class designed to keep those specific customers who have a preference for vegan products

The CustomerNames is the second subclass of the customers class, which contains two subclasses, BusinessNames and ConsumerNames. They hold individuals – the retail customers of the shop.

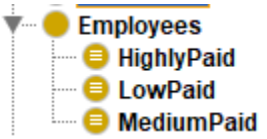

Figure 4: Employees Subclasses

The three subclasses of the Employees class contain some partition such as defined subclasses, which add some properties to individuals representing the employees, with some rules referring to their salary.

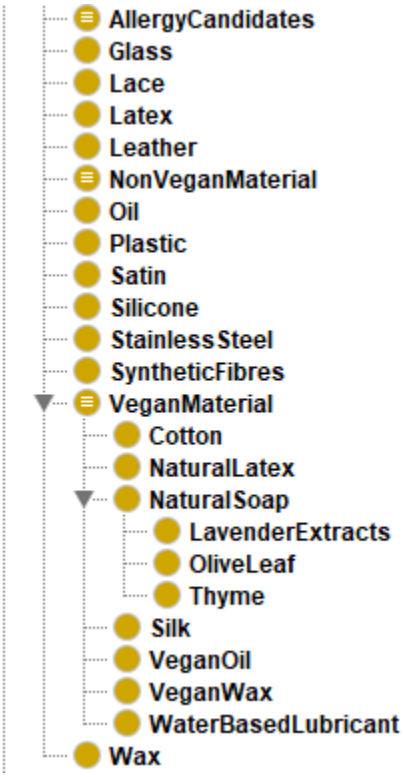

Figure 5: Materials Subclasses

Materials class contains various generic categories of materials as its subclasses. The central concept for these subclasses is assigning them to each product with an object property and adding individuals for different material classes. There are three defined classes, which categorize the materials to potential allergens and to vegan and non-vegan materials, distinguishing those that have some particular bio identity without much preprocessing.

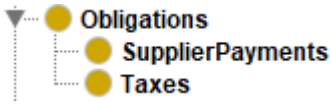

Figure 6: Obligations Subclasses

The subclasses of the Obligations contains two classes; one is the Taxes, a fixed amount, defined with an individual and the other, the SupplierPayments, contains individuals representing some categories that act as payments for suppliers.

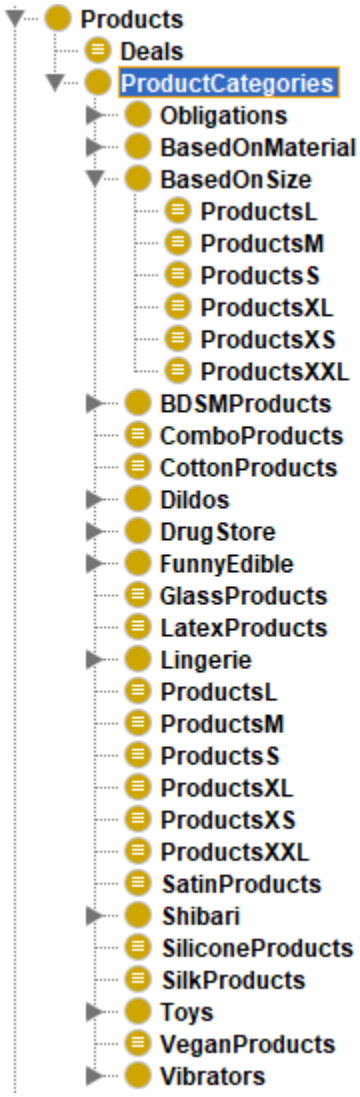

Figure 7: Product Subclasses

The backbone of the ontology are the subclasses of products. Each subclass represents a distinct category of products. There are both primitive and defined classes here. The primitive classes contain further subclasses, which hold individuals, which are the names of the products for each class. In general, the final level of each class contains individuals. The defined classes are connected to the Materials classes or some partitioning class via some object property. The idea behind their creation is to act as filters on the e-catalog. This is accomplished with the inferred knowledge created from the reasoner resulting in a form of an online catalog.

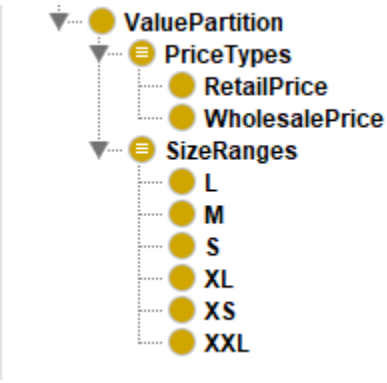

Figure 8: ValuePartition Subclasses

Additionally, the subclasses of the ValuePartition are used to partition the Products and Customers classes. The SizeRanges class contains classes for different size ranges assigned to products via object properties, while the PriceTypes class contains classes for two different types of pricing: RetailPrice and WholesalePrice that are used to partition the retail customers and the business customers.

Disjoint classes

To ensure that OWL Classes do not overlap, and therefore an individual that has been asserted to be a member of one of the classes in the group is not a member of any other classes in that group, classes of the same level are disjoint.

Restrictions of Classes

Cardinality Restrictions

In OWL, the class of individuals with at least (min), at most (max), or precisely a specified number (exactly) of relationships with other individuals is described by Cardinality Restrictions. ‘Minimum’ restriction is utilized for describing the Individuals of ComboProducts, while ‘exactly’ restriction for the Individuals of Deals class, as deals are some product offers with discount and as a result consist of a product categories’ combination.

Defined and Primitive Classes

In OWL, the classes are either defined or primitive. Primitive classes only have necessary conditions such as the classes of ContactInfo and Obligations. Defined classes apply necessary and sufficient conditions for membership in a class. Thus, a defined class allows deduction in two directions. Such classes relate to customer’s characteristics, the manufacturers, that by nature should be uniquely defined, and the ‘design pattern’ value partition.

Enumerated Classes

Enumerated classes are anonymous classes – they are the class of the individuals listed in the enumeration: they are listed (separated by commas) inside curly brackets—such a class in ontology is the CountryOfOrigin class holding as individuals the restrictions for the class definition.

Complement Classes

Complement classes contain all of the individuals that are not contained in the class that it is the complement to. Such class was created to distinguish the NonVeganMaterials with the VeganMaterials.

Object Properties

The creation of object properties is a crucial next step in an ontology, displaying the relationships between individuals.
Four main sections are created to distribute the object properties:

- Customer Object Property including buyAt, buyProductsOf, canCommunicate, hasPersonalSignature, has Preferences and isAllergicTo
- Manufacturer Object Property including hasCountryOfOrigin, produce, receiveSupplierPayments
- Product Object Property including hascontainer, hasSize, isMadeOf, isPrefferedBy, and producedBy
- SexShop Object Property including general information and duties of the store such as hasContactInfo, hasMonthlyObligations, and salesAt.

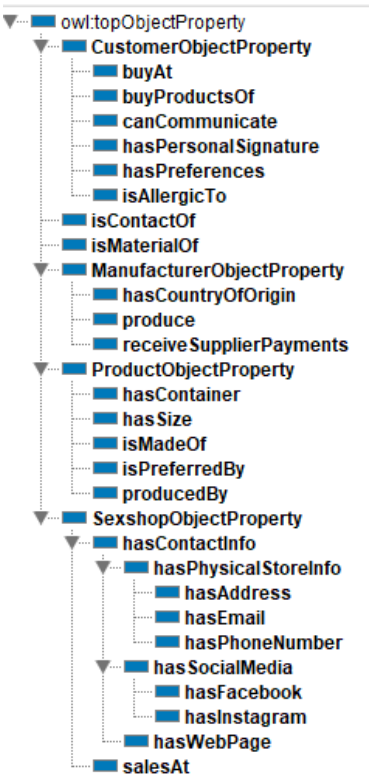

Figure 9: Object properties

Object property axioms

SubObjectPropertyOf	25
EquivalentObjectProperties	0
InverseObjectProperties	4
DisjointObjectProperties	0
FunctionalObjectProperty	11
InverseFunctionalObjectProperty	0
TransitiveObjectProperty	8
SymmetricObjectProperty	0
AsymmetricObjectProperty	0
ReflexiveObjectProperty	0
IrrefexiveObjectProperty	0
ObjectPropertyDomain	18
ObjectPropertyRange	18
SubPropertyChainOf	0

Figure 10: Object properties summary

Functional object properties

Functional object property means that for any given individual, the property could have at most one value. In case, multiple individuals are specified as values for the property, then these values will be inferred to denote the same object (Protégé 5 Documentation, n.d.). The object properties that are considered functional are the following: buyAt, hasPersonalSignature, hasCountryOfOrigin, receiveSupplierPayments, hasSize, hasAddress, hasEmail, hasPhoneNumber, hasFacebook and hasInstagram.

Transitive object properties

A single “hop” is implied over a chain of two along with a given property if that property is transitive (Protégé 5 Documentation, n.d.). The object properties that are considered transitive are BuyProductsOf, hasPreferences, isContactInfoOf, produce, isPreferredBy, hasPhysicalStoreInfo and hasSocialMedia.

Inverse object properties

Each object property may have a corresponding inverse property. The object properties that are considered inverse are the following pairs: isMadeOf - isMaterialOf, isPreferredBy - hasPreferences, isContactInfo - hasContactInfo, produce – producedBy.

Data properties

Data properties connect a single subject with some form of attribute data. Data properties have defined datatypes, including string, integer, date, date-time, or boolean. They are often defined to have a domain class, specifying the class membership of the individuals serving as subjects for each data property statement.

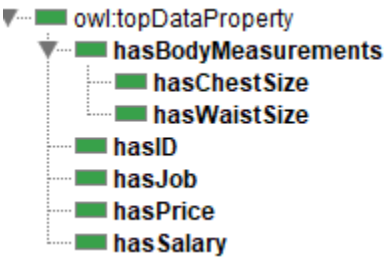

Figure 11: Data properties

Data properties may be functional, acting like functional object properties. Such properties are hasPrice and hasID that refer to the Products, and hasChestSize and hasWaistSize that refer to the Consumers are functional, as they uniquely describe the individuals.
Assuming that Employees can have multiple roles in a company, hasJob and hasSalary are not considered to be functional.

Individuals

Knowledge base is created by defining individual instances of classes, and so the ontology is populated. Most individuals created in the ontology serve as employees, products, country of origin, manufacturers, customers, and customer categories. They are assigned to classes and given data properties from Figure 11. After using the reasoner, inferred knowledge is created for individuals with such properties and is connected even further with others.

Results

In this section, the inferred class hierarchy that computed by Protégé's reasoner (HermiT 1.4.3.456), visual representation utilizing online tools, as well as SPARQL queries, that retrieve information from the ontology are being discussed.

Inference

As discussed in previous sections, inferred knowledge gain from the reasoner resembles of a catalog either from the customer's aspect, where the products are categorized by product category or material category, or business owner's aspect, where the company's obligations or employees are categorized under the same category.

Using the reasoner of Protégé, the classification of the products based on materials and size are shown in Figure 12 and Figure 13. Notice that on the Asserted class hierarchy, the subclasses of the products based on materials and size do not have any pre-defined children classes, while in the Inferred class hierarchy, children classes containing inferred knowledge are created.

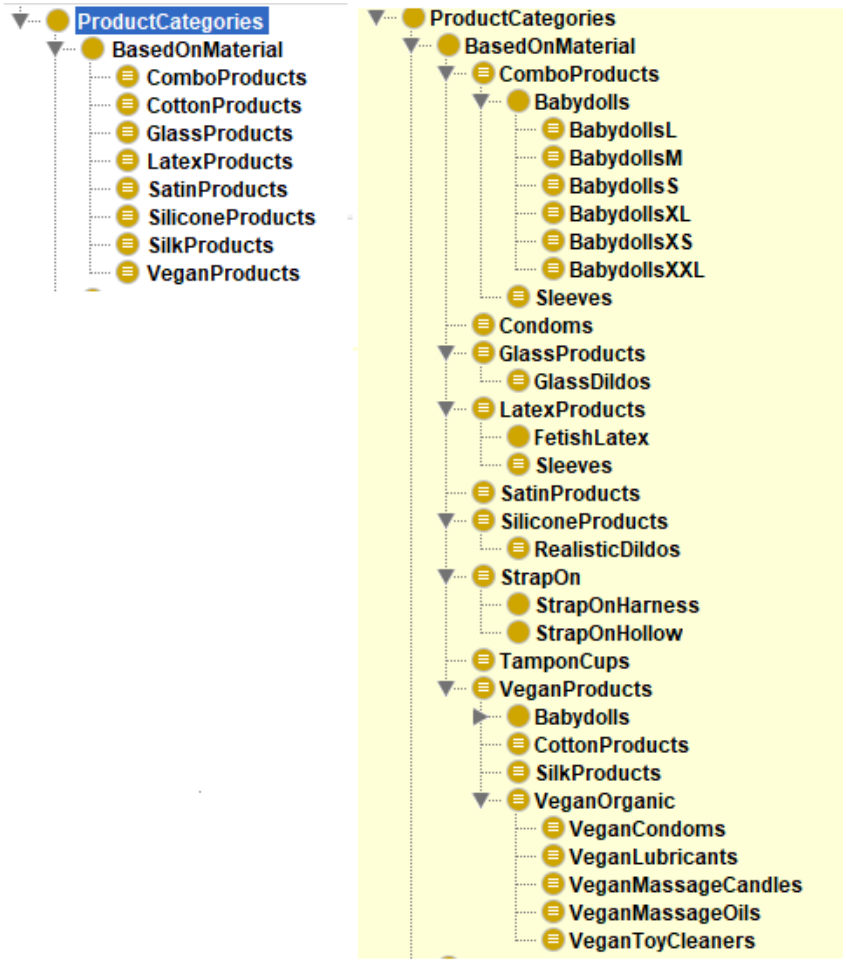

Figure 12: Asserted vs. Inferred knowledge: BasedOnMaterials

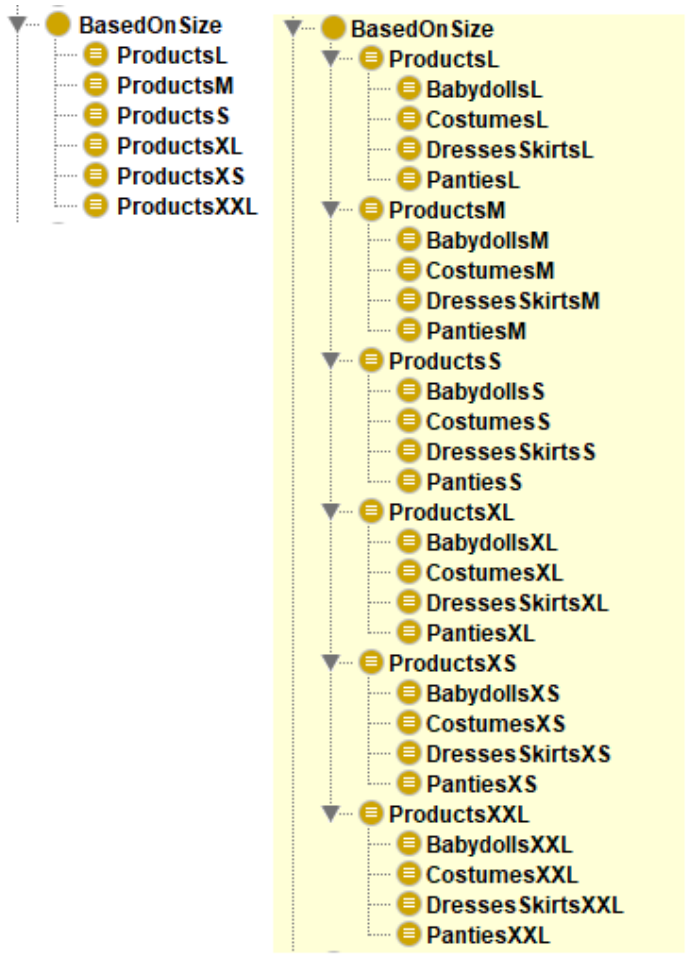

Figure 13: Asserted vs. Inferred knowledge: BasedOnSize

In DrugStore class, VeganOrganic products is populated by all the products that are composed by vegan materials, as it is strictly defined to be equivalent to DrugStore and (isMadeOf only VeganMaterial).

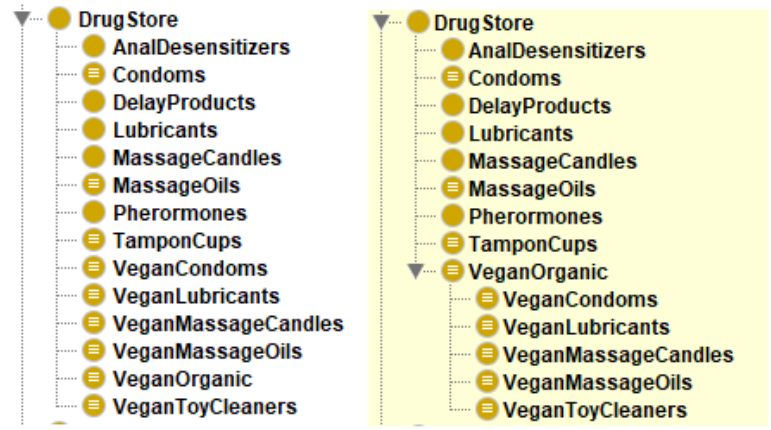

Figure 14: Asserted vs. Inferred knowledge: DrugStore

In Materials class, AllergyCandidates materials is populated by the potential allergens, as it is strictly defined to be equivalent to SyntheticFibres or Latex.

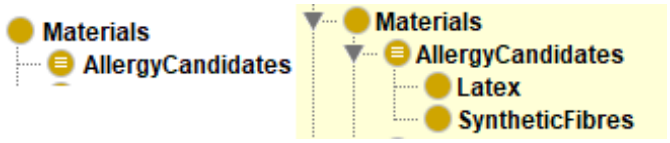

Figure 15: Asserted vs. Inferred knowledge: AllergyCandidates

Moreover, using the reasoner, the subclasses of the Employees class are populated by individuals. Highly, medium and low paid individuals have been categorized based on their salary.

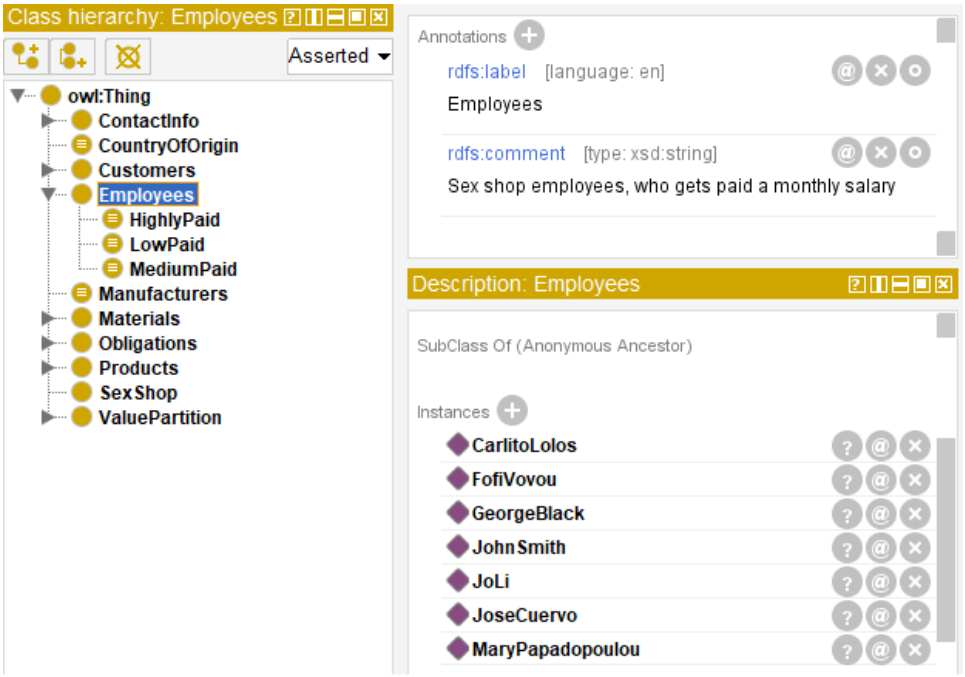

Figure 16: Asserted class hierarchy: Employees

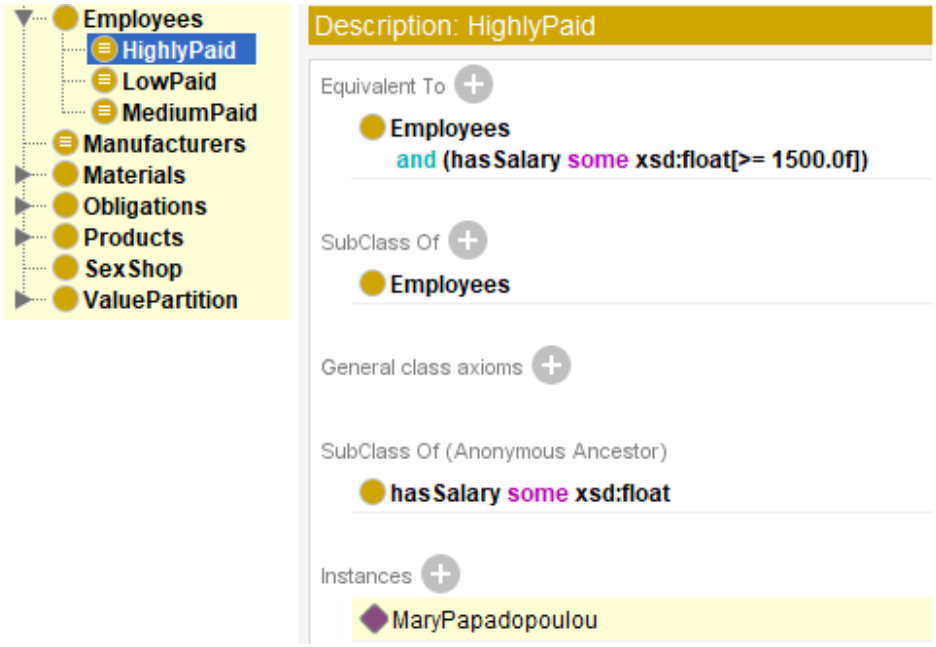

Figure 17: Asserted class hierarchy: HighlyPaid

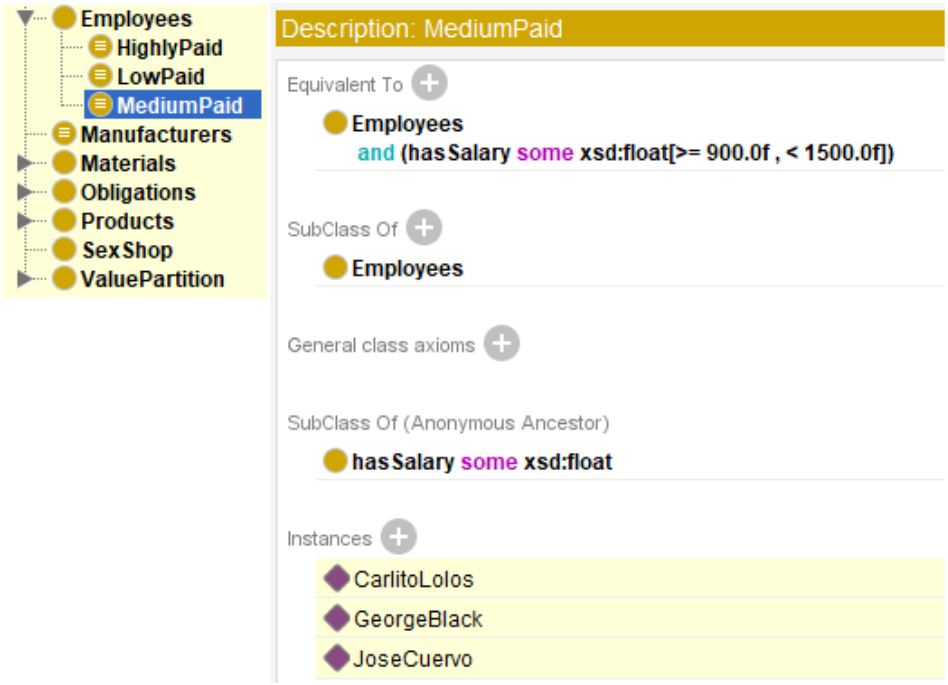

Figure 18: Asserted class hierarchy: MediumPaid

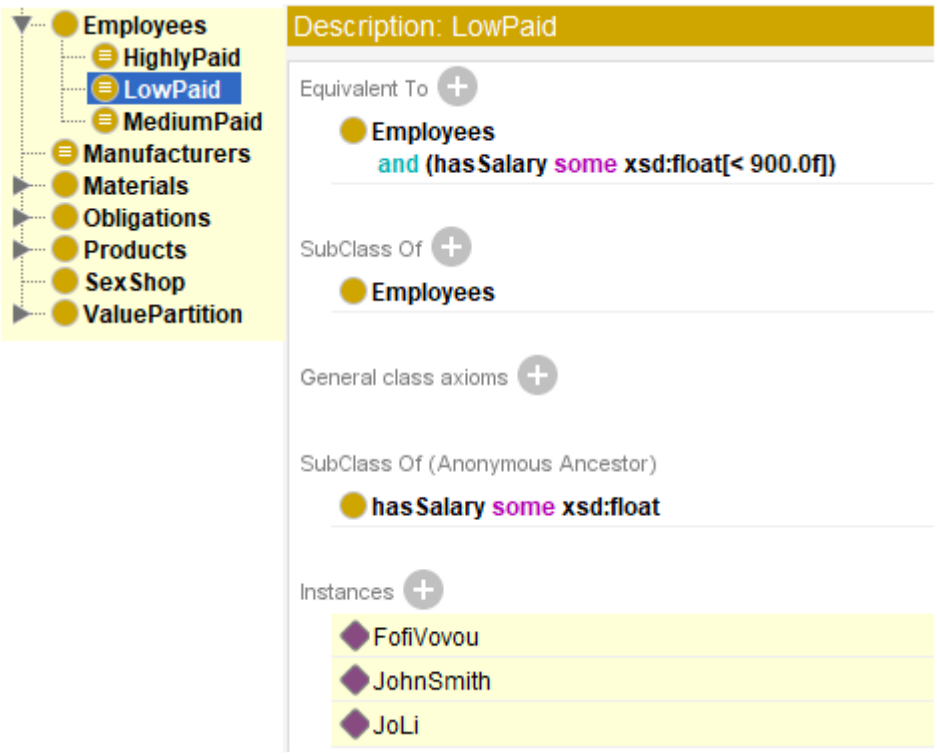

Figure 19: Asserted class hierarchy: LowPaid

Finally, inferred knowledge has been generated regarding CustomersCategories based on their preferences in specific categories of products and in vegan / non vegan products, their body measurements, and their allergies.

Figure 20: Asserted vs. Inferred knowledge: Lovers

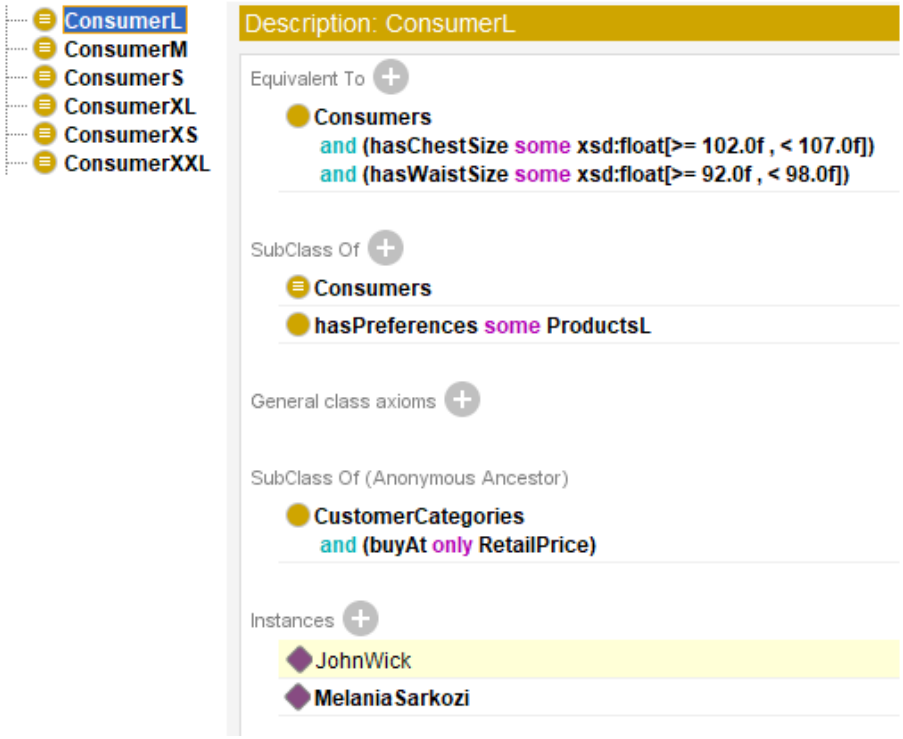

Figure 21: Asserted vs. Inferred knowledge: ConsumerL

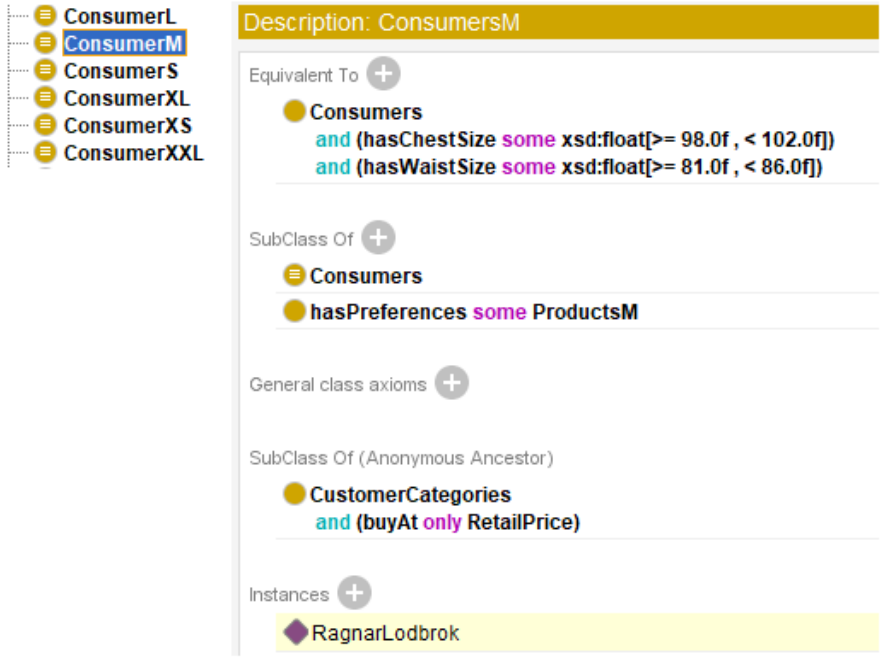

Figure 22: Asserted class hierarchy: ConsumerM

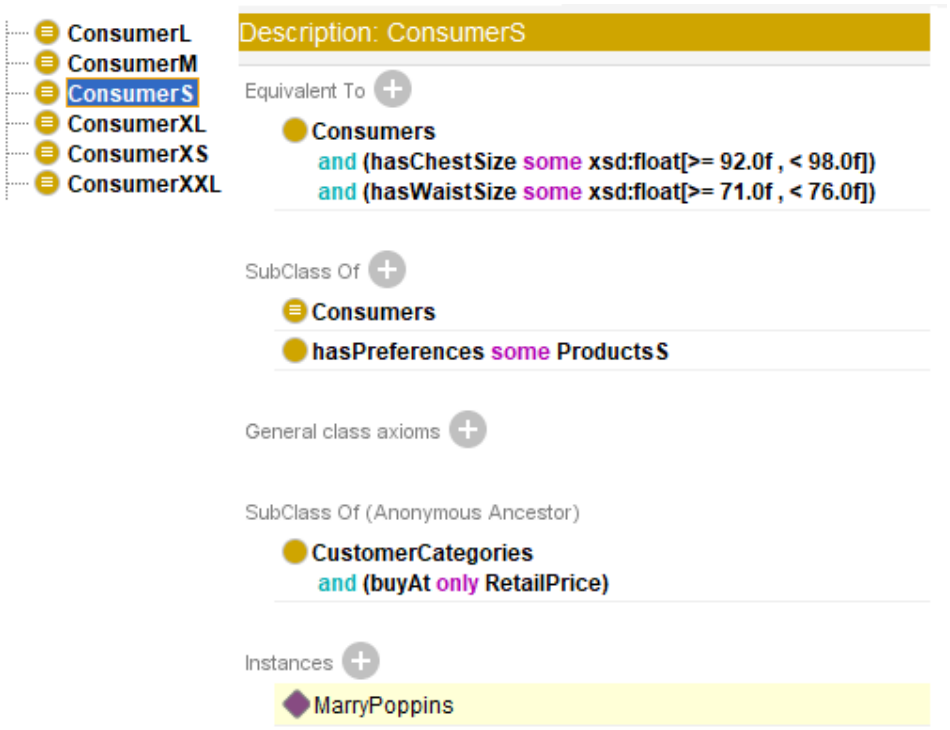

Figure 23: Asserted class hierarchy: ConsumerS

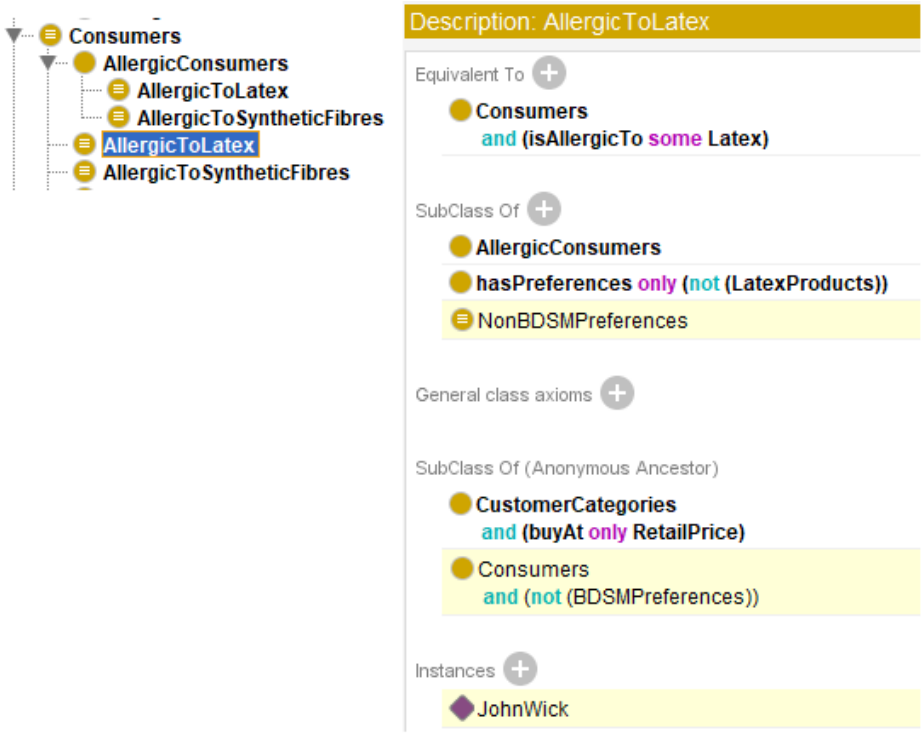

Figure 24: Asserted class hierarchy: AllergicToLatex

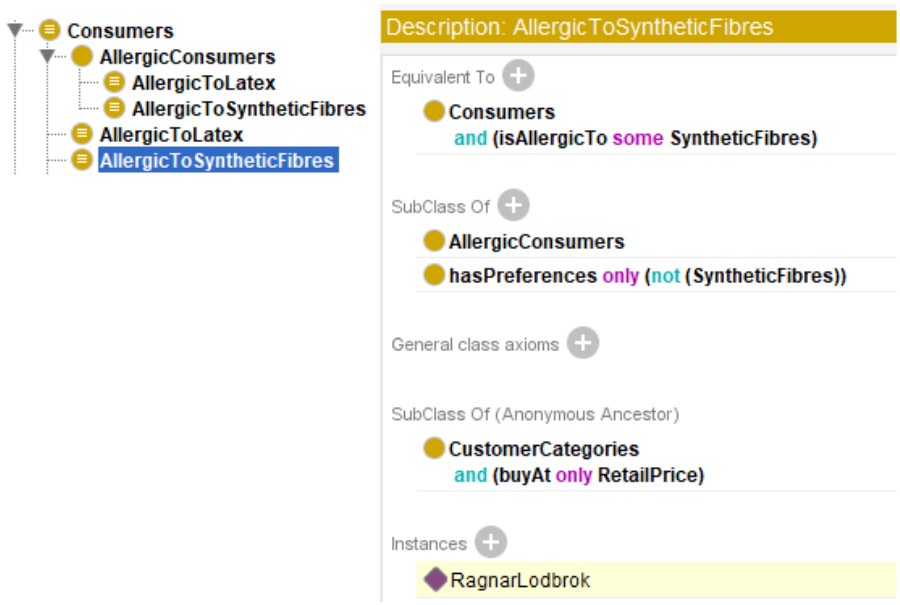

Figure 25: Asserted class hierarchy: AllergicToSyntheticFibres

The conclusion is that the inferred knowledge can classify either primitive or defined classes as subclasses of other classes. Great complexity generates a significant necessity to define classes and individuals strictly, to avoid problems while inferring knowledge. The closed-world assumption is adopted throughout the schema design, so everything that is destined to be added in the ontology, either class or individual, has to be strictly defined.

Closure axiom

A closure axiom on a property consists of a universal restriction that acts along the property to say that it can only be filled by the specified fillers. Such axiom is utilized for the ProductCategories based on materials. The current design of the hierarchy suggests that products of a certain material belong to the equivalent class. However, ProductCategories that are composed by a combination of minimum two materials are not individuals of either, but rather of a ComboProducts class .

Reasoner

While developing the ontology, the reasoner took longer to create connections or find problems caused by populating the ontology. Different reasoners were used to countering this issue, although nothing seemed to make a significant difference. The action that made an impact was the removal of Protégé resources' restrictions, that resulted in time reduction by 1/3 (one minute less).

Visual Representation

Visual representation often helps to concentrate information in an image which helps the reader understand the nature of a problem or a connection among classes. The tools used for the

following representations are a web tool, WebVOWL (http://www.visualdataweb.de/webvowl/), and an embedded visualization tool in the online form of Protégé.

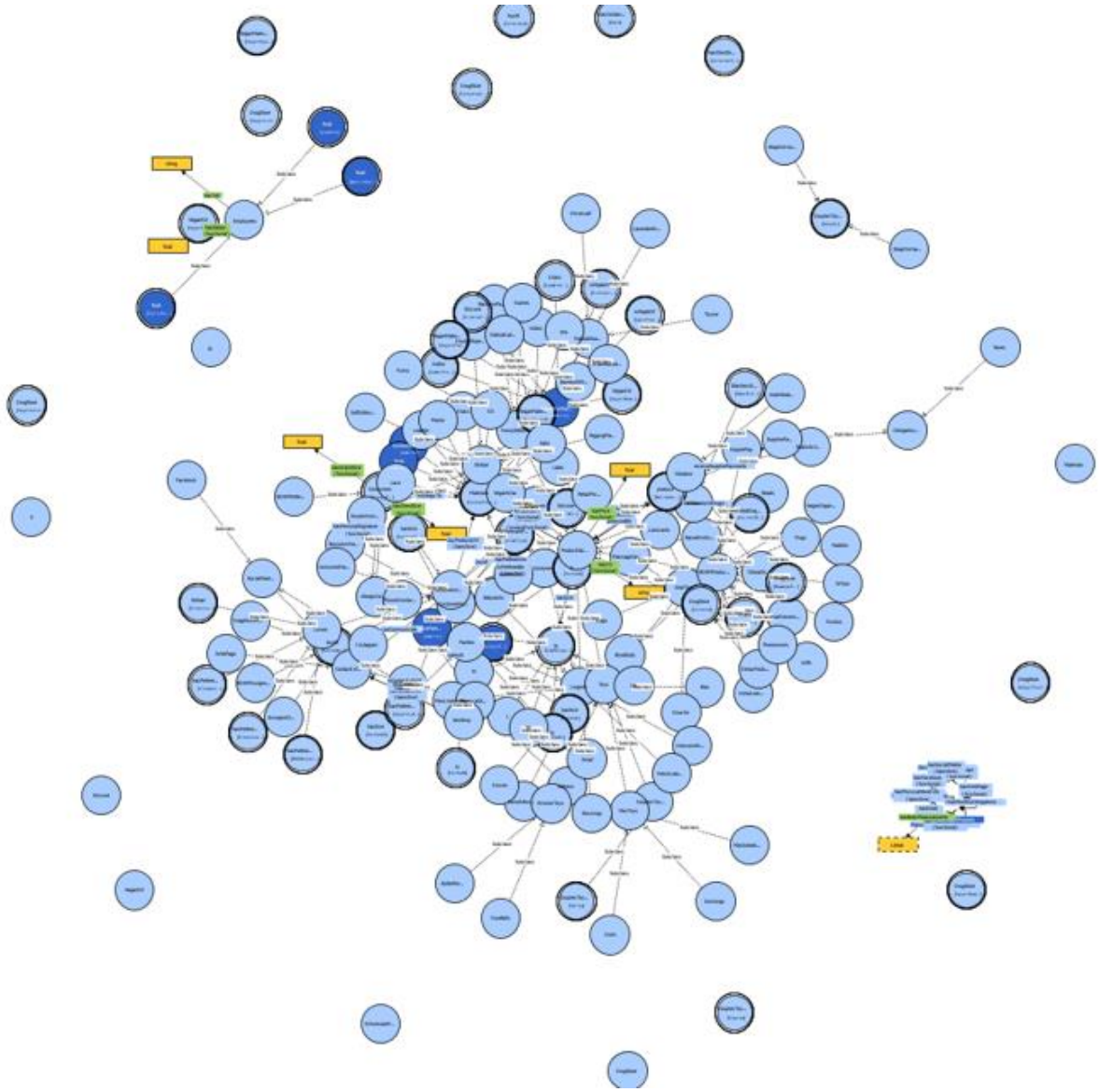

Figure 26: Ontology visualization using WebVOwl

As one may notice, the graph is dense. The way to isolate some parts of the graphic representation is either using filtering or zooming in and out; an excellent way to represent the data of an ontology.

The main differences with WebVOWL are the way of classes representation (different shape than a circle) and the ability to highlight by clicking a specific class. At the same time, online tools highlight the connections from the selected class through the last level.

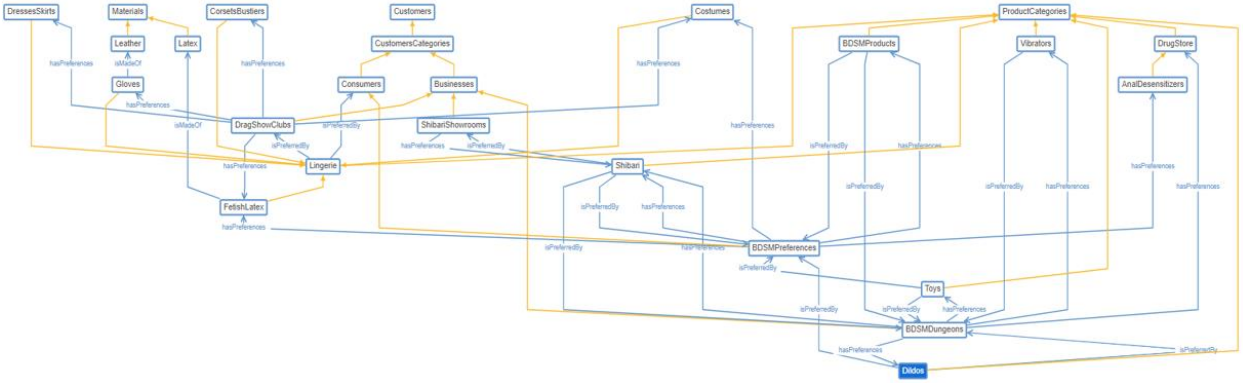

Figure 27: WebProtege Tool Visualization: an embedded tool in online protégé

SPARQL Queries

A key advantage of RDF data residing in an ontology form is that they can be queried despite their disparate sources since they are pre-linked. It is easy to query basic information like comments and labels or relationships among individuals since pre-defined prefixes can be used. However, creating new prefixes scales exponentially as the ontology grows and is usually a challenging and time-consuming task since there is no straightforward way to create the prefixes. Protege Desktop plug-in provides support for writing and executing SPARQL queries. Below there are some basic SPARQL queries. More can be found in Appendix I. It is worth mentioning that the goal is to use the ontology by Sex Shops as a database to query valuable results for the business like the name of the employees, the manufacturers, the number of available products, and other similar results.

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ss: <http://www.semanticweb.org/dimitra/ontologies/2021/5/untitled-ontology-11#>
SELECT *
WHERE { ?SexShop ss:hasAddress ?Address;
        ss:hasPhoneNumber ?PhoneNumber;
        ss:hasEmail ?Email;
        ss:hasWebPage ?WebPage;
        ss:hasFacebook ?Facebook;
        ss:hasInstagram ?Instagram.
}
```

Query 1: A Query to get all the information about the shop

Query 1 can be used to retrieve all information that qualifies as the contact information of the ontology so that the clients can be informed for the physical store's address, Facebook and Instagram page. The results may be found in the following figure below. A new prefix for the

primary ontology has been created, named “ss”, followed by the ontology’s International Resource Identifier (IRI). Since the query subject is the same, turtle notation is being used with the semicolon as a separator between each different predicate and object.

SexShop	Address	PhoneNumber	Email	WebPage	Facebook	Instagram
ErosArt	Foufoutos 57, Attiki	090-7485926	erosart@gmail.com	www.erosart.com	ErosArtTeam	ErosArtInsta

Figure 28: Query 1 results

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ss: <http://www.semanticweb.org/dimitra/ontologies/2021/5/untitled-ontology-11#>
SELECT ?employee ?position ?salary
WHERE { ?employee ss:hasSalary ?salary.
      ?employee ss:hasJob ?position
}

ORDER BY ASC (?salary)
```

Query 2: Retrieve all employees, their position, and their salary

Query 2 can retrieve some basic information about shop employees, with the result ordered in ascending manner by the salary, a float value. The results can be found in the figure below. The business occupies seven employees in various positions, like George Black, a cashier, and JoLi, responsible for the cleaning.

JoLi	"Cleaner"^^<http://www.w3.org/2001/XMLSchema#string>	"500.0"^^<http://www.w3.org/2001/XMLSchema#float>
FofiVovou	"StoreKeeper"^^<http://www.w3.org/2001/XMLSchema#string>	"750.0"^^<http://www.w3.org/2001/XMLSchema#float>
JohnSmith	"Sales"^^<http://www.w3.org/2001/XMLSchema#string>	"750.0"^^<http://www.w3.org/2001/XMLSchema#float>
JoseCuervo	"Delivery"^^<http://www.w3.org/2001/XMLSchema#string>	"1050.0"^^<http://www.w3.org/2001/XMLSchema#float>
CarlitoLolos	"Security"^^<http://www.w3.org/2001/XMLSchema#string>	"1110.0"^^<http://www.w3.org/2001/XMLSchema#float>
GeorgeBlack	"Cashier"^^<http://www.w3.org/2001/XMLSchema#string>	"1200.0"^^<http://www.w3.org/2001/XMLSchema#float>
MaryPapadopoulou	"SalesManager"^^<http://www.w3.org/2001/XMLSchema#string>	"2500.0"^^<http://www.w3.org/2001/XMLSchema#float>

Figure 29: Query 2 results

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
SELECT ?subject ?object
WHERE {?subject rdfs:comment ?object .
            FILTER regex(?object, "toys", "i")
}
```

Query 3: Retrieve all individuals with the word toy in the description

Query 3 will retrieve all toys with the word toys in their description, which is achieved with a regex filter.

AnalToys	"Toys destined for insertionin the rear end"@en
VeganOrganicToys	"Toys made of vegan and organic materials"@en
Dildos	"Sex toys that are used for insertion"^^<http://www.w3.org/2001/XMLSchema#string>
BachelorParty	"Edible toys for bachelor parties"@en
FunnyEdible	"Toys which can be eaten"@en
Vibrators	"Sex toys, with vibration, that are used for insertion"^^<http://www.w3.org/2001/XMLSchema#string>
VeganToyCleaners	"Products to keep your sex toys clean after use, made with vegan materials"@en
MenToys	"Gender specific toys for men"@en
Toys	"Objects or devices used for sexual stimulation or to enhance sexual pleasure. Toys are preferred by BDSMDungeons and BDSMPreferences (restriction)."@en
Whips	"Toys used to whip"@en
CouplesToys	"Toys for couples"@en
NipplePlay	"Toys used for nipple stimulation"@en
WomenToys	"Toys gender specific designed for female"@en

Figure 30: Query 3 results

Conclusion

The domain of e-commerce is expanding, and it has been a part of everyone's life. The recent global pandemic crisis resulted in the fast expansion of the industry. Shops that were not offering such services were forced to adopt the new normality and expanding their professional activities to e-commerce. To further scale the adaptability of the current project, some actions are needed, which are described below.

Due to high competition among organizations, it is a common practice that the collection of information is kept isolated and not accessible by other parts. However, the goal and future of information exchange is in open access solutions. Application independence of ontology enables a distributed model of information, while maintaining the knowledge- and database consistent. This model is the contribution that the Semantic Web infrastructure brings to a smarter Web. Removing the barriers of data silos would be beneficial to all the involved parties in the retail e-business sectors, and therefore a central ontology would play a key role in such an endeavor.
The project was designed to fulfill the needs of a particular domain in mind. To scale it up as a generalized solution, further complexity is required.

In terms of the ontology itself, an extension of certain classes and instances, that would generate more products, materials and customer categories, is suggested, resulting in a more concrete hierarchy. Personalized e-catalogs service systems should be viewed with a semantic query approach. Customer personalized ontologies could have an important role in e-commerce, as they could capture the customer's interests. This could be achieved by further expanding the existing ontology with classes that express customer characteristics, such as age-related classes. To get to the point that defined and primitive classes interact in a catalog manner, with filters and groupings that reflect and understand more the customers' needs, development must be done on the data properties and their accessibility with queries. For this cause, further research using Neo4j; the only enterprise-strength graph database combining native graph storage, advanced security, scalable speed-optimized architecture, and ACID compliance to ensure predictability and integrity of relationship-based queries (neo4j, 2021) and GraphDB; a highly efficient and robust graph database with RDF and SPARQL support (GraphDB, 2021). tools could help realize how the connections are created.

In terms of the ontology itself, an extension of certain classes (Products, Materials and Customers) is suggested, resulting in a more concrete hierarchy, where further inferred knowledge and an even more personalized recommendation system could be created. In this direction, additional customer characteristics, such as age, could be
In case, the extended version of the ontology was to be deployed as a catalog solution, a recommendation system could be interpreted. It could be a rather promising task and could upgrade user's experience in the e-catalogs. Besides, over the years, recommendation systems have become famous and the industry's standard for e-commerce pioneers, such as Amazon or other online service providers, such as Netflix.

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Appendix: Extra Queries

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
SELECT DISTINCT ?subject ?object
WHERE { ?subject rdfs:subClassOf ?object.
        ?object rdf:type owl:Class
}
```

Query 4: All subjects and objects connected by subclassOf predicate, where only classes are encoded as objects

ConsumerXL	Consumers
Address	PhysicalStoreInfo
PantiesXXL	Panties
WaterBasedLubricant	VeganMaterial
Beads	AnalToys
ProductsXL	BasedOnSize
Blindfolds	BDSMProducts
SwingersClubs	Businesses
PantiesS	Panties
Dolls	MenToys
WholesalePrice	PriceTypes
Butterflies	WomenToys
NonVeganMaterial	Materials
CustomerNames	Customers
Condoms	DrugStore
SatinProducts	BasedOnMaterial
BasedOnSize	ProductCategories
ProductsXXL	BasedOnSize
Gloves	Lingerie
Lovers	CustomerCategories

Figure 31: Query 4 results

The above table shows the query results where only distinct Classes and Subclasses appear to avoid duplicates. For example, Address is subClassOf PhysicalStoreInfo, and Gloves is subClassOf Lingerie.

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ss: <http://www.semanticweb.org/dimitra/ontologies/2021/5/untitled-ontology-11#>
SELECT ?company ?country
WHERE { ?company ss:hasCountryOfOrigin ?country.}

ORDER BY ASC (?country)
```

Query 5: List of Manufacturers by country

The above query returns all manufactures by country in ascending order.

AnalFantasy	China
ObsessiveLingerie	China
LoverBoy	France
Intense	France
BIOglide	Sweden
FetishFantasySeries	Sweden
LELO	Sweden
KingCock	USA
Durex	UnitedKingdom

Figure 32: Query 5 results

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ss: <http://www.semanticweb.org/dimitra/ontologies/2021/5/untitled-ontology-11#>
SELECT ?count (COUNT (?o) as ?count)
WHERE { ?s ss:hasPrice ?o.}
```

Query 6: Count of Number of Products

Figure 33: Query 6 results

The results of the following query get the products along with their prices in ascending manner.

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ss: <http://www.semanticweb.org/dimitra/ontologies/2021/5/untitled-ontology-11#>
SELECT ?product ?price
WHERE {?product ss:hasPrice ?price.}

ORDER BY ASC (?price)
```

Query 7: List of All Products with prices

KamaSutraComicPlayingCards	"6.5"^^<http://www.w3.org/2001/XMLSchema#float>
PassionG-String	"7.2"^^<http://www.w3.org/2001/XMLSchema#float>
GPBlack5MBondageRope	"8.8"^^<http://www.w3.org/2001/XMLSchema#float>
RedTemptasiaBondageTape	"10.8"^^<http://www.w3.org/2001/XMLSchema#float>
JoydivisionHotLadyTampons	"11.0"^^<http://www.w3.org/2001/XMLSchema#float>
FSDarkRoomCollar	"13.8"^^<http://www.w3.org/2001/XMLSchema#float>
FairSquaredVeganOriginal	"13.9"^^<http://www.w3.org/2001/XMLSchema#float>
IsildursBane	"15.0"^^<http://www.w3.org/2001/XMLSchema#float>
DurexExtraFeucht	"15.5"^^<http://www.w3.org/2001/XMLSchema#float>
GPMetalHandcuffs	"15.5"^^<http://www.w3.org/2001/XMLSchema#float>
GPXOXOPaddleBlack	"15.5"^^<http://www.w3.org/2001/XMLSchema#float>
Lover'sChoiceSexyGraffitiMango	"15.8"^^<http://www.w3.org/2001/XMLSchema#float>
BestBottomAss	"16.7"^^<http://www.w3.org/2001/XMLSchema#float>
DonaKissableMassageCandle	"18.0"^^<http://www.w3.org/2001/XMLSchema#float>
F.S.DarkRoomROOMFlogger	"18.8"^^<http://www.w3.org/2001/XMLSchema#float>
HempBondageRope	"18.9"^^<http://www.w3.org/2001/XMLSchema#float>
SystJoStrawberryKisses	"19.8"^^<http://www.w3.org/2001/XMLSchema#float>
BlindflodPink	"19.8"^^<http://www.w3.org/2001/XMLSchema#float>
ObsseciseS808StockingsBeige	"19.8"^^<http://www.w3.org/2001/XMLSchema#float>
FSDarkRoomHandCuffs	"19.8"^^<http://www.w3.org/2001/XMLSchema#float>

Figure 34: Query 7 results

The results of the following queries provide price filtering for the products. Query 8 provides the ten cheapest products in the ontology, while Query 9 limits products between 45 and 100 currency units.

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ss: <http://www.semanticweb.org/dimitra/ontologies/2021/5/untitled-ontology-11#>
SELECT ?product ?price
WHERE {?product ss:hasPrice ?price.}

ORDER BY ASC (?price)
LIMIT 10
```

Query 8: List of Top ten cheapest products

KamaSutraComicPlayingCards	"6.5"^^<http://www.w3.org/2001/XMLSchema#float>
PassionG-String	"7.2"^^<http://www.w3.org/2001/XMLSchema#float>
GPBlack5MBondageRope	"8.8"^^<http://www.w3.org/2001/XMLSchema#float>
RedTemptasiaBondageTape	"10.8"^^<http://www.w3.org/2001/XMLSchema#float>
JoydivisionHotLadyTampons	"11.0"^^<http://www.w3.org/2001/XMLSchema#float>
FSDarkRoomCollar	"13.8"^^<http://www.w3.org/2001/XMLSchema#float>
FairSquaredVeganOriginal	"13.9"^^<http://www.w3.org/2001/XMLSchema#float>
IsildursBane	"15.0"^^<http://www.w3.org/2001/XMLSchema#float>
DurexExtraFeucht	"15.5"^^<http://www.w3.org/2001/XMLSchema#float>
GPMetalHandcuffs	"15.5"^^<http://www.w3.org/2001/XMLSchema#float>

Figure 35: Query 8 results

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ss: <http://www.semanticweb.org/dimitra/ontologies/2021/5/untitled-ontology-11#>
SELECT ?product ?price
WHERE { ?product ss:hasPrice ?price.
        FILTER (?price >40 && ?price <100)
}

ORDER BY ASC (?price)
```

Query 9: List of Products with a value between 45 & 100

RuseJimmyCerise	"46.8"^^<http://www.w3.org/2001/XMLSchema#float>
MaleStationOilyDildo	"47.0"^^<http://www.w3.org/2001/XMLSchema#float>
MegazortXXLDildo	"55.0"^^<http://www.w3.org/2001/XMLSchema#float>
ActionmanLeatherWhip	"59.4"^^<http://www.w3.org/2001/XMLSchema#float>
BridgetBigBoobLoveDoll	"79.8"^^<http://www.w3.org/2001/XMLSchema#float>
BunnyCostume	"81.5"^^<http://www.w3.org/2001/XMLSchema#float>
DoubleDongHotPink	"82.5"^^<http://www.w3.org/2001/XMLSchema#float>
PumpWorxPro	"95.0"^^<http://www.w3.org/2001/XMLSchema#float>

Figure 36: Query 9 results

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ss: <http://www.semanticweb.org/dimitra/ontologies/2021/5/untitled-ontology-11#>
SELECT ?s ?o
WHERE {?s ss:hasID ?o .
        FILTER regex(?o, "047", "i")
}

ORDER BY ASC (?s)
```

Query 10: List of Products with specific fragments in their ID

BunnyCostume	"0102.047.00036"^^<http://www.w3.org/2001/XMLSchema#string>
F.S.DarkRoomROOMFlogger	"0405.047.00012"^^<http://www.w3.org/2001/XMLSchema#string>
FSDarkRoomCollar	"0406.047.00025"^^<http://www.w3.org/2001/XMLSchema#string>
FSDarkRoomHandCuffs	"0406.047.00026"^^<http://www.w3.org/2001/XMLSchema#string>
GPXOXOPaddleBlack	"0405.019.00047"^^<http://www.w3.org/2001/XMLSchema#string>
PassionG-String	"0104.047.00360"^^<http://www.w3.org/2001/XMLSchema#string>

Figure 37: Query 10 results

Query 11 required the creation of a new prefix for all the BDSM products in the ontology. The name “bdsmpr” has been created to declare the prefix, again followed by the IRI.

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX prod: <http://www.semanticweb.org/dimitra/ontologies/2021/5/untitled-ontology-11#ProductCategories>
PREFIX bdsmpr: <http://www.semanticweb.org/dimitra/ontologies/2021/5/untitled-ontology-11#BDSMProducts>
SELECT ?subject ?comment
WHERE {?subject rdfs:subClassOf bdsmpr:.
      ?subject rdfs:comment ?comment
}

ORDER BY ASC (?subject)
```

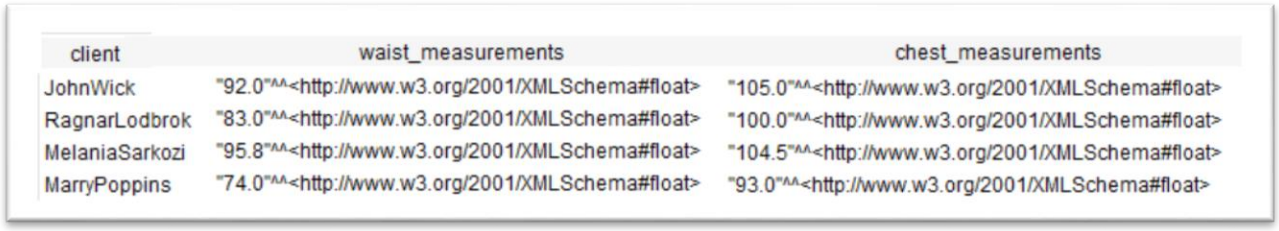
Query 11: List of all BDSM Products with their description

Blindfolds	"Items which limits the wearers vision"^^<http://www.w3.org/2001/XMLSchema#string>
Cuffs	"Items which limits the wearer's motion"@en
CollarLeash	"A collas and a leash set, preferred by BDSM customer"@en
Whips	"Toys used to whip"@en
NipplePlay	"Toys used for nipple stimulation"@en
Paddles	"Items for spanking"@en
VeganOrganicToys	"Toys made of vegan and organic materials"@en
Gags	"A gag is usually an item or device designed to prevent speech, often as a restraint device to stop
Ticklers	"Products used for tickling"@en

Figure 38: Query 11 results

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ss: <http://www.semanticweb.org/dimitra/ontologies/2021/5/untitled-ontology-11#>
SELECT ?client ?waist_measurements ?chest_measurements
WHERE {?client ss:hasWaistSize ?waist_measurements;
            ss:hasChestSize ?chest_measurements.}
```

Query 12: List of Clients and their body measurements

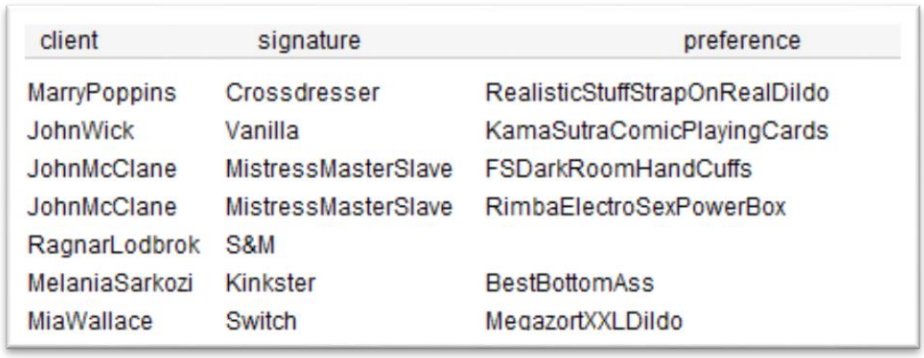


client	waist_measurements	chest_measurements
JohnWick	"92.0"^^<http://www.w3.org/2001/XMLSchema#float>	"105.0"^^<http://www.w3.org/2001/XMLSchema#float>
RagnarLodbrok	"83.0"^^<http://www.w3.org/2001/XMLSchema#float>	"100.0"^^<http://www.w3.org/2001/XMLSchema#float>
MelaniaSarkozi	"95.8"^^<http://www.w3.org/2001/XMLSchema#float>	"104.5"^^<http://www.w3.org/2001/XMLSchema#float>
MarryPoppins	"74.0"^^<http://www.w3.org/2001/XMLSchema#float>	"93.0"^^<http://www.w3.org/2001/XMLSchema#float>

Figure 39: Query 12 results

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ss: <http://www.semanticweb.org/dimitra/ontologies/2021/5/untitled-ontology-11#>
SELECT ?client ?signature ?preference
WHERE {?client ss:hasPersonalSignature ?signature.
OPTIONAL {?client ss:hasPreferences ?preference.}
}
```

Query 13: List of Clients with their Signature and Preference



client	signature	preference
MarryPoppins	Crossdresser	RealisticStuffStrapOnRealDildo
JohnWick	Vanilla	KamaSutraComicPlayingCards
JohnMcClane	MistressMasterSlave	FSDarkRoomHandCuffs
JohnMcClane	MistressMasterSlave	RimbaElectroSexPowerBox
RagnarLodbrok	S&M	
MelaniaSarkozi	Kinkster	BestBottomAss
MiaWallace	Switch	MegazortXXLDildo

Figure 40: Query 13 results

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ss: <http://www.semanticweb.org/dimitra/ontologies/2021/5/untitled-ontology-11#>
SELECT ?client ?waist_measurements ?chest_measurements ?signature ?preference
WHERE {?client ss:hasPersonalSignature ?signature;
            ss:hasPreferences ?preference;
            ss:hasWaistSize ?waist_measurements;
            ss:hasChestSize ?chest_measurements.
}
```

Query 14: List of Customers with their information – a combination of Queries 12 and 13

client	waist_measurements	chest_measurements	signature	preference
JohnWick	"92.0"^^<http://www.w3.org/2001/XMLSchema#float>	"105.0"^^<http://www.w3.org/2001/XMLSchema#float>	Vanilla	KamaSutraComicPlayingCards
MelaniaSarkozi	"95.8"^^<http://www.w3.org/2001/XMLSchema#float>	"104.5"^^<http://www.w3.org/2001/XMLSchema#float>	Kinkster	BestBottomAss
MarryPoppins	"74.0"^^<http://www.w3.org/2001/XMLSchema#float>	"93.0"^^<http://www.w3.org/2001/XMLSchema#float>	Crossdresser	RealisticStuffStrapOnRealDildo

Figure 41: Query 14 results