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Towards an Ontology-based approach to the "new normality" after COVID-19: the Spanish case during pandemic first wave

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Abstract: The impact of the pandemic caused by COVID-19 has been immense in all fields of human activity. In most of the affected countries, the authorities have decreed a series of legal measures to try to stop the growth of the disease and the number of people affected by it. These legal measures involved, in most cases, restrictions on the free movement of people and on work and trade activities, new hygiene procedures, and social distancing. In the particular case of Spain, the rapid evolution of the pandemic led to the declaration of a so-called state of alarm and a period of confinement in private homes. The novelty of the situation and the large number of official decrees approved may have led to confusion among the Spanish population in some cases. In this context, in this paper we present an ontological approach that could be the germ of a knowledge base on the measures approved by the Spanish Government in relation to the pandemic during the so-called first wave (March-June 2020). This ontology has been developed in OWL (Ontology Web Language) for its possible compatibility with semantic web-based applications and allows the consultation of statements related to various aspects of daily life during this period.

Key words: Applications, decision support, ontology, legal restrictions, COVID-19

1. Introduction

COVID 19 (coronavirus disease 2019) is an infectious disease caused by a coronavirus. The World Health Organization (WHO) declared a pandemic situation about this disease on March 11, 2020, due to its rapid spread. During 2020, the high contagiousness of the virus, together with the lack of effective vaccine forced many national governments to adopt restrictive measures on mobility, confinement, commercial activity, among others, with the objective of avoiding the collapse of health systems.

The aim of this paper is to implement an ontology-based approach to storage, semantic reasoning, and consultation of those legal norms derived from the pandemic situation in Spain during the so-called "first wave" (March-June 2020). More than a hundred legal documents were issued only at the state level during this period. Such legislative complexity gave rise to a series of doubts among the Spanish population about what was permitted at each stage and under what conditions. The possible advantages of this type of ontology have been pointed out in previous works such as [1]:

- To be a formal communication channel between the actors involved (legislators, scientists, population in general).

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- A skeleton of a knowledge base for future and better informed discussions to determine the effectiveness of the measures implemented, once the urgency of the actions has disappeared.
- Reuse of knowledge in similar situations that may occur in the future.
- Integration into multidisciplinary information systems.
- It can be a basis for ad hoc processing applications on compliance with the rules imposed in certain situations.

To this end, we will first briefly describe the chronology of the main events that occurred in Spain during this period as this information will better explain the rest of the article. Next, the author will cite a series of antecedents in the literature related to the application of ontologies to describe legislative regulations. After this analysis, the author will describe the structure of the proposed ontology in general and applied to a particular case: the walking out of children under 14 years old. After that, a proposal for implementation/adaptation is detailed also with some test carried out in the context of this paper. The last section will be dedicated to the open lines of the work and its limitations.

2. Brief chronology of the COVID-19 in Spain (first wave)

This section attempts to show a chronology of the main events that occurred in Spain during the first wave of the COVID-19 pandemic. It is not an exhaustive analysis, as the main reason for its inclusion in this paper is to allow the reader to better understand the subsequent sections.

The first cases of COVID-19 were reported in China in late December 2019. After rapid progress in different countries, on the 31st of January 2020, the National Centre for Microbiology in Spain confirmed the first case of coronavirus in the country. It was a German tourist on holiday on the island of La Gomera. He was isolated until he recovered a few weeks later. On the 26th of February, the first case not imported from abroad was confirmed in Seville. The first death was reported on the 3rd of March: a male who died on the 13th of February in Valencia and whose death was initially attributed to severe pneumonia. Following this notification, events were precipitated by the large increase in the number of cases recorded. On the 9th of March, several regional governments decreed a suspension of school activities. The following day, the Spanish government suspended flights to Italy, the main focus of the disease at the time in Europe.

On 13th March, Spanish President Pedro Sanchez (based on the recommendations of experts such as the Director of the Health Alert and Emergency Coordination Centre of the Spanish Ministry of Health, Fernando Simón) declared a so-called "state of alarm" for an initial period of 15 days, which could be extended [2]. This decree meant in practice the confinement of the population to their homes, allowing only some departures as for the purchase of food. The state of alert also implied the reduction of economic activity only to sectors declared as essential, as well as the definition of the national government as the sole responsible authority.

The first extension of the state of alert (28th of March) led to a tightening of the confinement, as it forced all non-essential service workers to remain in their homes for two weeks. This situation was reversed to conditions similar to those of the first days of the state of alert in the second extension decreed on the 12th of April. The number of cases registered at that time was about 166,000 and the number of deaths reached 17,000. From late March to early April, more than 900 deaths per day from the disease were officially recorded[1].

[1]Spanish Health Ministry. COVID-19 Pandemic Status in Spain [online]. Website https://www.mscbs.gob.es/profesionales/saludPublica/ccayes/alertasActual/nCov/home.htm [accessed 16 March 2021].

On the 26th of April, the third extension of the state of alarm occurs, which included a first measure of relaxation of the confinement. Children under 14 years of age were allowed to go out for a walk once a day, for a maximum duration of one hour, between 9 a.m. and 9 p.m., accompanied by a responsible adult, without having access to playgrounds [2]. This measure had a great social impact on Spanish society, which had been confined for more than 40 days.

From this point, the process of de-escalation of the situation is designed, towards what has been called "new normality" and implemented through the successive extensions of the state of alarm, every fifteen days until the last one, in effect until the 21st of June. This process of moving towards the "new normality" consisted of four phases (from Phase 0 to Phase 3). Every two weeks, the different territorial units defined by the authorities could progress through the different phases according to the state of the epidemic in them. There was a possibility of regression if conditions were not favourable. As an example, the following list describes some of the restrictions associated with the so-called Phase 1.

- Opening of bar and restaurant terraces with a maximum capacity of 50 %.
- Meetings are allowed in homes of up to 10 people.
- Circulation within the territorial unit.
- Resumption of all activities in the agri-food and fisheries sectors.

3. Related work: ontologies and legislation

Ontologies can be defined as formal models for the expression of knowledge and are currently used in numerous fields of research and development. In this sense, the author would like to highlight the following quoted definition, which is rather adjusted to the context of this paper: "a well-founded mechanism for the representation and exchange of structured information" [3].

In relation to the objective of this work, the author will mention several recent works related to the use of ontologies in the field of legislation. This analysis is intentionally not exhaustive, as the reader interested in a more in-depth comparison can find it in [4]. Much effort has been made to semantically structure different sets of laws into what is commonly called a legal ontology. Initiatives such as Akoma Ntoso [5], legal knowledge interchange format (LKIF) [6], MetaLex [6] or LEXML [7] are aimed at defining standards for the exchange and interoperability of legal documents. However, it is noted that lexical and terminological ambiguity is a serious problem in the implementation of a legal ontology [8]. Therefore, in our opinion, one must be realistic about the intrinsic limitations of ontology design in this field. Thus, in Kondrashov's words [9]:

"The law has certain inherent properties that won't let fully entrust its making and enforcement to AI (…) Too many clauses and exceptions will have to be made when transforming the polysemantic terms into computers' language. Thus, the law itself would have to be transformed first."

With regard to specific cases of application, Gupta et al. [10] implement a legal knowledge base of Chinese legal documents. For this purpose, they analyze over one million judicial decision documents. The resulting ontology proposed focuses on each of the actors and elements in a judicial act. Giord [11] presents an

[2] Boletín Oficial del estado (Spain). BOE web siteOrden SND/370/2020, de 25 de abril, sobre las condiciones en las que deben desarrollarse los desplazamientos por parte de la población infantil durante la situación de crisis sanitaria ocasionada por el COVID-19./Order SND/370/2020, of 25 April, on the conditions under which children should be displaced during the health crisis caused by COVID-19 (in Spanish) [online]. Website https://www.boe.es/boe/dias/2020/04/25/ [accessed 22 April 2021]

argument-based legal research search engine model, where the arguments are assigned as nodes in an ontology tree.

Mockus and Palminari [12] have developed an ontology named as Ontology of Open Government Data Licenses Framework for a Mash-up Model (OGDL4M) for qualifying and connecting each applicable legal rule to official legal texts. Castro Júnior et al. [13] introduce an ontology in order to improve results of data mining in judicial decisions database. Rabinia and Ghanavati [14] develop a new goal modeling framework based on Goal-oriented Requirements Language (GRL) to facilitate the automation of the legal requirements modeling process. Geko and Tjoa [15] propose an ontology-based data protection knowledge base, interpendent of both the General Data Protection Regulation (GDPR) (adopted by the European Union-Commission) and information security. Palmirani [5] points how to apply Akoma Ntoso to FAO Resolutions. Francesconi and Governatori [16] design an ontology-based approach for legal compliance checking within a Linked Open Data framework, through the use of properties restrictions able to be processed by Ontology Web Language (OWL) reasoners.

Leone and Di Caro [17] identify standard use cases in data protection field with the aim of sharing existing knowledge formalizations. Alves Soares, Ventura Martins and Rodrigues da Silva [18] introduce the LegalLanguage, a domain-specific language for the authoring and specification of laws. Palminari et al. [19] develop a ontology called PrOnto (Privacy Ontology) by using the MeLOn (Methodology for building Legal Ontology) methodology. This ontology is designed to support legal reasoning and check compliance.

Another work to highlight is Eunomos [20], a legal document management system based on legislative XML and ontologies. Bartolini, Muthuri and Santos [21] propose a bottom-up ontology for the description in the field of data protection and its relationships. Chalkidis et al. [22] are the responsibles of Nomothesia, a web application for the access to the Greek legislation. Waltl, Reschenhofer and Matthes [23] implement a decision support system to represent the semantics of legal norms, making use of MxL (Model Based Expression Language). Fawei et al [24] present a system to model and implement the automatic application of legal knowledge using a rule-based approach, using Semantic Web Rule Language (SWRL). Maftuhah, Purwarianti and Asnar [25] design a method for the representation of a Indonesian Republic regulation into an ontology for reasoning systems.

4. Proposed ontology

As can be seen from the bibliographic references, there are multiple alternatives to follow for the implementation of a legal ontology. This fact demonstrates the versatility and adaptability in the field, but it also suggests a difficulty in the elaboration of a standard that covers the multitude of different cases involved. Moreover, after a more in-depth analysis of the references mentioned, the resulting option is the design of an ad hoc ontology for each case, which will optimize the computational performance. This does not preclude that one or more of the above proposals can be adapted to a specific case. The resulting design seeks the simplification of interoperability rather than the complexity of semantic completeness, taking into account the limitations indicated by Kondrashov. In this sense, for example, in this work an ontology has been designed that is compatible with a subset of the Hohfeldian model of law [26], but does not cover it in its entirety. This ontology allows the semantic characterization in the legislative sense for the construction of a knowledge base.

An important detail is the delimitation of the legislation to be covered by the ontology to a reduced set of Spanish legislation (the one related to the measures resulting from the pandemic episode) in a limited period of time. This allows us to approach the task of elaborating the ontology in a systematic way, without the complications typical of the semi-automatic translation into a formal system of a field not specifically designed for it. Even this task would be more complicated given the characteristics of the Spanish language, where there is no strict word order in the syntactic structure. Even with these restrictions in mind, a series of tests were initially carried out with existing systems for the elaboration of ontologies from natural language. The FRED tool was used to evaluate the complexity and goodness of ontology translation, but was discarded because it offered a cumbersome structure (derived in large part from the complex nature of administrative language and the commented characteristics of the Spanish language) that was difficult to reuse and connect between the different concepts that appeared in the legislative documents.

With reference to the proposed ontology, we will focus from now on describing its elements. Ontologies are usually composed of concepts, relationships, instances and axioms (valid rules in the domain model). There are several tools for its implementation, although Protégé is the tool used in the vast majority of ontology designs. Protégé is free, W3C standards compliant and open-source with a vast user community. Regarding the ontology language, the author have used OWL, whose specification depends directly on the W3C and that offers great possibilities of semantic interoperability.

Due to the nature of the ontology and to provide it with versatility, it is necessary to introduce the possibility of using classes as property values. This need is quite common when building an ontology. However, this is not possible in the OWL DL and OWL Lite varieties (two OWL subsets that do not cover all the specifications but guarantee the processing of the resulting ontology). W3C indicates several possibilities to perform this action. Taking into account the scalability and use of the ontology, we have chosen to create special instances of the class to be used as property values. This option has the disadvantage of the necessary maintenance of the set of instances, but in this case it is preferable to other more complex options or with compatibility problems in the reasoning.

In this case, the modeling objects in the knowledge base are the constraints that arise from the declaration of the alarm state, so the ontology will focus on that subset of the legal speech. However, the ontology can be easily extended to include other types of legal acts/specific regulations, such as those indicated in [16]. As suggested above, one of the design criteria is the simplicity of the ontology, regardless of the details inherent in the legal field. The intention is to indicate to possible users what they can do at a given moment. With this configuration (and the limitation to a reduced period and legislative package), a minimum treatment of the legal cross-references resolution has been chosen. This intended simplicity allows, again, the easy inclusion of new elements and types of documentation.

As expected from such a legal ontology, the author will include both legal and real-world concepts in it. The main classes of the ontology are shown in Figure 1. The main unit of the ontology is going to be the class Statement, which can be described as the set of elements of the legislation linked in a semantic and temporal way. An example of Statement can be the one related to the opening of places of worship in a concrete phase of the de-escalation process.

The Statement class is enriched with a series of classes, object properties and data properties that act as metadata and facilitate searches within the ontology. First, the hasStatementCategoryType property allows to define one or several categories for the Statement class. To do this, several instances of a class called StatementCategoryType are defined. Examples are ChildrenCategotyType, UseOfPublicSpacesCategoryType, and RestaurantOpeningCategoryType. Other information includes the phase of the epidemic episode to which the Statement relates and the date the provision takes effect. This allows you to filter searches and process

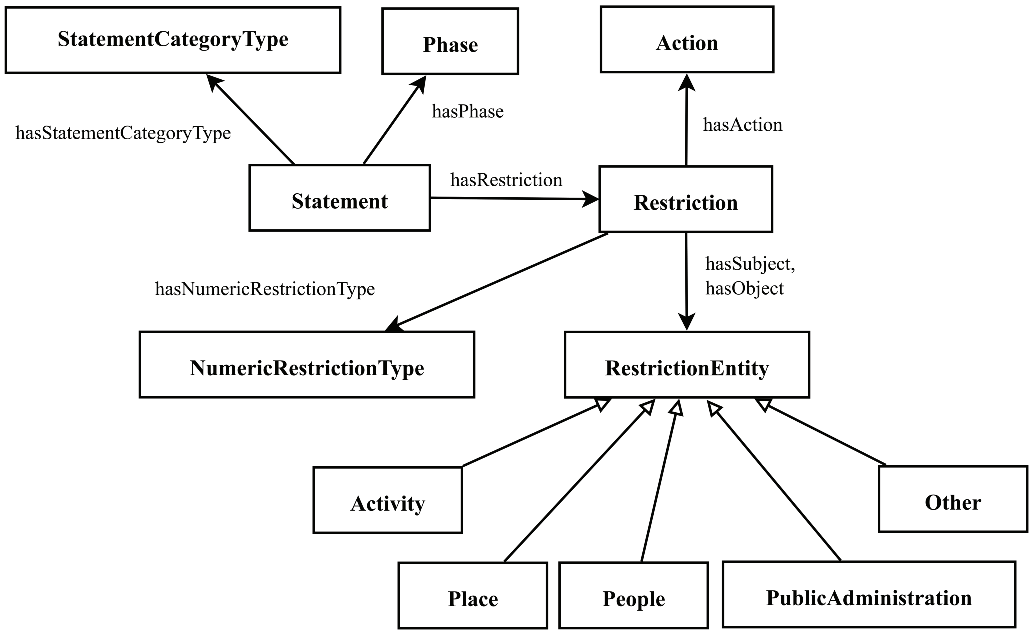

Figure 1. Main classes in the proposed ontology.

updates of the various legal provisions. Therefore, the ontology includes the hasPhase and hasStartDate properties.

An important aspect is the hasRestriction property, which allows relating the Statement class with a class called Restriction. This Restriction class models in the knowledge base the conditions imposed by the authorities. A Statement has as many hasRestriction relationships as restrictions involved. The expression 1 indicates this link through DL syntax.

$$hasRestriction^I \subseteq StatementI^I xRestriction^I \tag{1}$$

Each restriction is formalized by five properties (four object properties and one data property). In this way it is possible to include the entities related (instances of the RestrictionEntity class) with the actions involved (instances of the Action class) and their possible numerical modifiers. For these modifiers a new NumericRestrictionType class is used, which determines the nature of the restriction limitation through its instances (lower or upper limit, inclusive or exclusive, exact or no restriction). Finally, the value of the numerical constraint (if any) is included by means of a character string formed as a Well-Known Text (WKT) formed by the value and the unit of measure. This type of inclusion simplifies the structure and formation of the search string. For example, the restriction ”a store must have a customer occupancy of at most one half of its capacity” could be expressed as follows:

$$\begin{aligned} < RestrictionImpl, StoreImplementation >&: hasSubject \\ < RestrictionImpl, hasOccupancy >&: hasAction \\ < RestrictionImp, CustomerImplementation >&: hasObject \\ < RestrictionImp, IncludingUpperLimitType >&: hasNumericRestrictionType \\ < RestrictionImp, 50.00; \% >&: hasWKTValue \end{aligned} \tag{2}$$

where a series of instances of the corresponding classes have been defined so that they can be objects of the corresponding properties.

Other properties, classes and instances are added to this basic ontology skeleton to cover the different restrictions that appear in the Official State Bulletin in Spain (BOE) during the alarm period. These new definitions are compatible with the original structure. A non-exhaustive list of these secondary definitions is shown in Table 1. Regarding the definition of data and object properties, the corresponding domains and ranges have been defined. For example, the ontology includes the object property hasResponsibleAdult (with domain Children and range Adult) and the data property hasCOVID symptoms, with domain People and range xsd:boolean.

Table 1. Other subclasses in the ontology.

Class	Subclasses
Statement	ForceMajeureSituationStatement, NonForceMajeureSituationStatement
People	COVID19Suspect, NoCOVID19Suspect, PeopleByAge, PeopleByTownPopulation, ThirdParty
PeopleByAge	Adult, Children, PeopleFrom14Under18
Adult	AdultByAge, DomesticEmployee, ResponsibleAdult
Place	BusinessPlace. ChildrenPlayground, Home, SportsArea, Town
PublicAdministration	AutonomousRegionGovernment, SpanishGovernment
Town	LessThan5000PopulationTown, PlusThan5000PopulationTown

5. An example: children can go out for a walk

The implementation process is detailed below, where the information about name space prefixes has been omitted for the sake of simplicity. As a first step, an instance of the type Statement is created, with its descriptive properties: effective date, category, etc.

$$Statement(ChildrenWalkingStatement)^I \tag{3}$$

Some of the identified restrictions instances are carried out through the definition of new instances of the classes defined in the ontology, while others, due to their definition nature, are solved through SWRL rules or a combination of both options. Of those seen in Table 2, the following are analyzed in depth.

Table 2. Restrictions derived from legislation about children's walk (Spanish Official State Bulletin, 25th April 2020.

Restriction #	Description
R1	For the purposes of this order, children shall mean persons under the age of 14.
R2	The circulation is limited to a daily walk.
R3	Such circulation is limited (...) lasting a maximum of one hour.
R4	Such circulation is limited (...) at a distance of no more than one kilometer from the child's home.
R5	Such circulation is limited (...) between 9 a.m. and 9 p.m.
R6	Children who present symptoms or are in home isolation due to a diagnosis of COVID-19, or who are in home quarantine because they have had contact with someone with symptoms or diagnosed with COVID-19, may not make use of the authorization contained in the previous section.
R7	The daily walk should be done in groups of a maximum of one responsible adult and (...)
R8	The daily walk should be done in groups of a maximum of (...) and up to three children.
R9	During the daily walk, an interpersonal distance of at least two meters must be maintained with third parties.
R10	Access to outdoor children's play areas and (...) will not be permitted.
R11	Access to outdoor (...) sports facilities will not be permitted.
R12	For the purposes of this order, a responsible adult is a person of legal age living in the same household as the child at present, or a household employee in charge of the child.
R13	When the responsible adult is a person other than the parents, guardians, conservators, foster parents or legal or de facto guardians, he or she must have prior authorization from them.

Restriction 1: For the purposes of this order, children shall mean persons under the age of 14. In this case, the Children subclass and the corresponding SWRL rule are defined.

$$\begin{aligned} Children^I \subseteq People^I \\ People(?x) \wedge \; hasAge(?x, ?age) \wedge \; swrlb : lessThan(?age, 14) \rightarrow Children(?x) \end{aligned} \tag{4}$$

Restriction 4: Such circulation is limited (...) at a distance of no more than one kilometer from the child's home. The necessary instances are defined and those values corresponding to the defined properties are given.

$$
\begin{aligned}
Restriction(DistanceFromHome1KmRestriction)^I \\
Place(PlaceImplementation)^I \\
Home(HomeImplementation)^I \\
< DistanceFromHome1KmRestriction, PlaceImplementation >: hasSubject \\
< DistanceFromHome1KmRestriction, PlaceImplementation >: hasAction \\
< DistanceFromHome1KmRestriction, HomeImplementation >: hasObject \\
< DistanceFromHome1KmRestriction, IncludingUpperLimitType >: hasNumericRestrictionType \\
< DistanceFromHome1KmRestriction, "1; kilometer;" >: hasWKTValue \\
< ChildrenWalkingStatement, DistanceFromHome1KmRestriction >: hasRestriction
\end{aligned}
\tag{5}
$$

Restriction 12: For the purposes of this order, a responsible adult is a person of legal age living in the same household as the child at present, or a household employee in charge of the child. In this case, the following elements are defined in the ontology, two subclasses and two SWRL rules.

$$
\begin{aligned}
DomesticEmployee^I \subseteq Adult^I \\
Adult^I \subseteq People^I \\
Adult(?x) \wedge Children(?y) \wedge livesWith(?x, ?y) \rightarrow hasResponsibleAdult(?y, ?x) \\
DomesticEmployee(?x) \wedge Children(?y) \wedge isInChargeOf(?x, ?y) \rightarrow hasResponsibleAdult(?y, ?x)
\end{aligned}
\tag{6}
$$

This structure allows the execution of searches, using standard languages for this purpose, SPARQL (a recursive acronym that stands for. SPARQL Protocol and RDF Query Language) or SQWRL (Semantic Query-Enhanced Web Rule Language). For illustrative purposes, the following expression implies a search expressed in SQWRL for the list of restrictions in the case of children's walk.

$$
\begin{aligned}
Statement(?x) \wedge hasStatementCategoryType(?x, ChildrenWalking) \wedge hasRestriction(?x, ?y) \wedge \\
hasSubject(?y, ?a) \wedge hasObject(?y, ?b) \wedge hasAction(?y, ?z) \wedge \\
hasNumericRestrictionType(?y, ?c) \wedge hasWKTValue(?y, ?d) \rightarrow sqwrl : select(?x, ?y, ?a, ?z, ?b, ?c, ?d)
\end{aligned}
\tag{7}
$$

6. Proposal of implementation and test

In this section, we will first address the issue of how to integrate the proposed ontology into external applications, e.g., those based on web-based systems or accessed via mobile devices. As can be deduced from the previous sections, a user can perform queries directly through the Protégé tool about statements and restrictions. The result of the search can be accessed using the SQWRL Tab of Protégé, where the readability of the result can be considered as sufficient for expert users. However, this is not the only way to interact with the ontology. An example of other type of interaction is described in Figure 2. The proposed ontology together with the implemented SWRL rules are processed by an application capable of handling this type of rules. In this work, SWRLAPI has been used, although there are other proposals with similar functionality, such as SWRLJessBridge. This process results in an ontology with terms inferred from the rules, which can be queried by external applications. These queries can be expressed in languages such as SQWRL (as shown in the Figure 2) or SPARQL.

The use of the aforementioned applications is generally quite straightforward for implementation. As a sample, the following code corresponds to the use of SWRLAPI.

```
// creation of an OWL ontology
OWLOntologyManager ontologyManager = OWLManager.createOWLOntologyManager();
OWLOntology ontology =   ontologyManager.loadOntologyFromOntologyDocument(owlFile);
OWLDataFactory df = ontology.getOWLOntologyManager().getOWLDataFactory();
// create a SWRL rule engine and infer
SWRLRuleEngine ruleEngine = SWRLAPIFactory.createSWRLRuleEngine(ontology);
ruleEngine.infer();
// create a SQWRL engine and get the results
SQWRLQueryEngine queryEngine = SWRLAPIFactory.createSQWRLQueryEngine(ontology);
SQWRLResult result = queryEngine.runSQWRLQuery("q1", queryString);
```

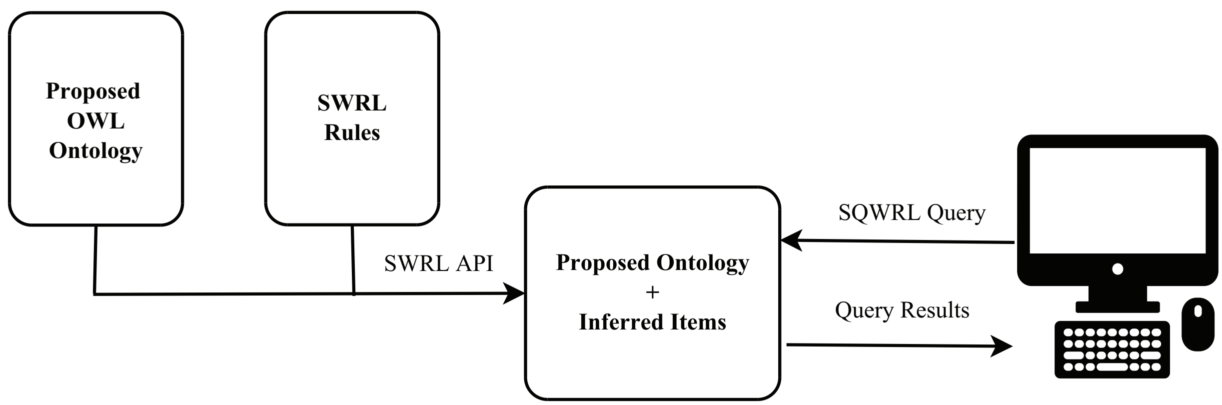

Figure 2. An example of flow for ontology inclusion in third-part applications.

The semantic consistency of the resulting ontology has been successfully tested using Pellet reasoner, included in the Protégé environment. Another possible focus of interest is on the suitability of the concepts included in the proposed ontology. The tests carried out confirm that the defined terms allow the encoding of the type of restrictions found in the legislation. Also related to the possible ideology of the terms included in the ontology, the author point to the results obtained by [27]. According to that work, it is not possible to determine the best semantic content for a given domain from statistical information in the ontology.

Another test performed with the proposed ontology is the response time to a SQWRL search as the number of instances of the Statement class in the ontology increases. For each individual, the relationships and individuals have been defined according to Figure 1. The calculations have been carried out on the same equipment used in other works by the author [28], that is an Intel®Core™ i7-2600 CPU @ 3,40 GHz processor, 8GB RAM. This allows a comparison of the simplicity/complexity of the proposed ontology with respect to those works. The results are shown in Figure 3. As can be seen, for a case of 11,000 individuals in the Statement class, the search time is just under 10 s. This result can be considered as satisfactory. One of the main reasons for these measurements is the fact that the proposed ontology does not rely on third party sources.

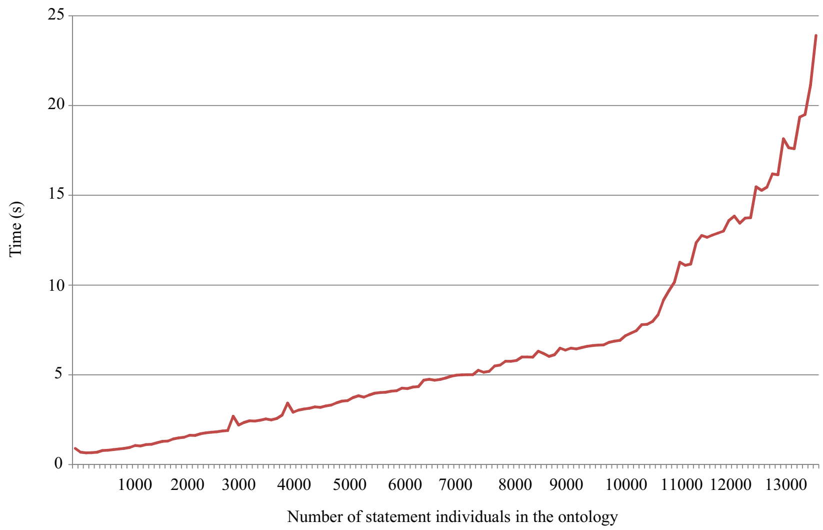

Figure 3. Results from SQWRL searches in Protégé.

7. Conclusion

In this article, the author provided an ontology-based design to efficiently describe the legal restrictions suffered in Spain during the first-wave episode of the COVID-19 pandemic (March-June 2020). The proposed ontology is based on a work unit called Statement that can be described as the set of elements of the legislation linked in a semantic and temporal way. In addition to allowing a semantic search by the user, this configuration could allow the study of the pandemic episode from various points of view, including legislative and social. The proposed ontology can also serve as a basis for the implementation of ad hoc systems to verify if a certain situation in the real world complies with the legal regulations expressed in the knowledge base. This type of structure makes it possible to provide a knowledge base for computer applications without the need to recompile code, simply by adding axioms to the ontology. In this sense, the proposed ontology is accessible through several implementation perspectives. In this work, it has been implemented using SWRL API and SQWRL queries.

The ontology has been created from the information that appeared in the Spanish BOE. However, the efficient structure of the ontology can be used to include other sources of information such as legislation approved by regional authorities, since the design allows a progressive definition of the knowledge involved. It should be clarified that following the end of the state of alarm, co-governance of the situation was agreed between the central government and the regional authorities. The latter were primarily responsible for defining new restrictions and their management.

One of the strengths of the proposed ontology is its simplicity. This makes it easily extensible but also efficient at search execution time. Precisely the possibility of performing searches is one of the most practical functionalities of this work. It has been determined that for an ontology with 11,000 individuals of the Statement class, the time of an SQWRL search is less than 10 s.

The use of ontology in this field requires frequent updating of the restrictions dictated by the authorities. A further step would be an automatic loading process into the ontology. However, difficulties related to natural language processing in the legislative domain would have to be addressed.

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E.J. Gonzalez gave the idea, did the experiments, interpreted the results, and wrote the paper.

References

[1] Pileggi S, Lamia S. Climate change TimeLine: An ontology to tell the story so far. IEEE Access 2020; 8: 65294-65312. doi: 10.1109/ACCESS.2020.2985112.

[2] Carrero O, García, F. Changes in Journalism during the state of alarm in Spain: The use of video in El País [Cambios en el Periodismo durante el estado de alarma en España: El uso del video en El País] . Estudios Sobre el Mensaje Periodistico 2021; 27 (1): 295-306 (in Spanish). doi: 10.5209/esmp.71302

[3] Ye J, Coyle L, Dobson S, Nixon P. Ontology-based models in pervasive computing systems. The Knowledge Engineering Review 2007; 22 (4): 315-347. doi: 10.1017/S0269888907001208

[4] Leone V, Di Caro L, Villata S. Taking stock of legal ontologies: A feature-based comparative analysis. Artificial Intelligence and Law 2020; 28: 207-235. doi: 10.1007/s10506-019-09252-1

[5] Palmirani M. Akoma Ntoso for making FAO resolutions accessible. Frontiers in Artificial Intelligence and Applications 2019; 317: 159-169. doi: 10.3233/FAIA190018

[6] Boer A, Winkels R, Vitali F. Proposed XML standards for law: MetaLex and LKIF. In: 2007 Conference on Legal Knowledge and Information Systems: JURIX 2007: The Twentieth Annual Conference; Leiden, The Netherlands; 2007, pp. 19-28.

[7] De Martim H, Lima JADO, Araujo LC. Base of brazilian legal norms: An open government data initiative [base de normas jurídicas brasileiras: Uma iniciativa de open government data]. Perspectivas em Ciencia da Informacao 2018; 23 (4): 133-149 (in Portuguese). doi: 10.1590/1981-5344/3567

[8] Kurcheeva G, Rakhvalova M, Rakhvalova D, Bakaev M. Mining and indexing of legal natural language texts with domain and task ontology. In: Electronic Governance and Open Society: Challenges in Eurasia. EGOSE 2018. Communications in Computer and Information Science; St. Petersburg, Russia; 2019. pp. 123-137.

[9] Kondrashov I, Ivanov A, Zschage H, Pronin A, Sergo A et al. Legaltech i yuristy budushchego: kommentariiekspertov [Legaltech and the future lawyers: experts' comments]. Law 2017; 11: 20-36 (in Russian).

[10] Gupta A, Wang AZ, Lin K, Hong H, Sun H et al. Toward building a legal knowledge-base of chinese judicial documents for large-scale analytics. In: Wyner A, Casini G. (editors). Frontiers in Artificial Intelligence and Applications, vol 302, Legal Knowledge and Information Systems. 2017. pp. 135-144.

[11] Giord M. LexrideLaw: An argument based legal search engine. In: International Conference on Artificial Intelligence and Law; London, UK; 2017. pp. 271-272.

[12] Mockus M, Palmirani M. Legal ontology for open government data mashups. In: 7th International Conference for E-Democracy and Open Government, CeDEM 2017; Danube University Krems, Austria; 2017. pp. 113-124.

[13] Castro AP, Calixto WP, Gomes VM, Veiga EF, Silva LFA et al. Ontology applied in the judicial sentences. In: 2017 CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies, CHILECON 2017 ; Pucón, Chile; 2017. pp. 1-6.

[14] Rabinia A, Ghanavati S. The FOL-based legal-GRL (FLG) framework: Towards an automated goal modeling approach for regulations. In: 8th International Model-Driven Requirements Engineering Workshop, MoDRE 2018; Banff, AB, Canada; 2018. pp. 58-67.

[15] Geko M, Tjoa S. An ontology capturing the interdependence of the general data protection regulation (GDPR) and information security. In: CECC 2018 Central European Cybersecurity Conference; Ljubljana, Slovenia; 2018. pp. 1-6.

[16] Francesconi E, Governatori G. Legal compliance in a linked open data framework. In: Araszkiewicz M, Rodríguez-Doncel V (editors). Frontiers in Artificial Intelligence and Applications, vol 322, Legal Knowledge and Information Systems. 2019. pp. 175-180.

[17] Leone V, Di Caro L. Frequent use cases extraction from legal texts in the data protection domain. In: Araszkiewicz M, Rodríguez-Doncel V (editors). Frontiers in Artificial Intelligence and Applications, vol 322, Legal Knowledge and Information Systems. 2019. pp. 193-198.

[18] Soares AA, Martins PV, da Silva AR. LegalLanguage: A domain-specific language for legal contexts. In: Advances in Enterprise Engineering XIII 9th Enterprise Engineering Working Conference, EEWC 2019, Revised Papers, Lecture Notes in Business Information Processing; Lisbon, Portugal; 2020. pp. 33-51.

[19] Palmirani M, Martoni M, Rossi A, Bartolini C, Robaldo L. PrOnto: Privacy ontology for legal reasoning. In: 7th International Conference, EGOVIS 2018; Regensburg, Germany; 2018. pp. 139-152.

[20] Boella G, Caro LD, Humphreys L, Robaldo L, Rossi P et al. Eunomos, a legal document and knowledge management system for the web to provide relevant, reliable and up-to-date information on the law. Artificial Intelligence and Law 2016; 24 (3): 245-283. doi: 10.1007/s10506-016-9184-3

[21] Bartolini C, Muthuri R, Santos C. Using ontologies to model data protection requirements in workflows. In: JSAI International Symposium on Artificial Intelligence, New Frontiers in Artificial Intelligence 2015; Kanagawa, Japan; 2017. pp. 233-248.

[22] Chalkidis I, Nikolaou C, Soursos P, Koubarakis M. Modeling and querying greek legislation using semantic web technologies. In: European Semantic Web Conference ESWC 2017: The Semantic Web; Portorož, Slovenia; 2017. pp. 591-606.

[23] Waltl B, Reschenhofer T, Matthes F. Modeling, execution and analysis of formalized legal norms in model based decision structures. In: Pagallo U, Palmirani M, Casanovas P, Sartor G, Villata S (editors). AI Approaches to the Complexity of Legal Systems. AICOL 2015, AICOL 2016, AICOL 2016, AICOL 2017, AICOL 2017, 2018, pp. 157-171.

[24] Fawei B, Wyner A, Pan JZ, Kollingbaum M. Using legal ontologies with rules for legal textual entailment. In: Pagallo U, Palmirani M, Casanovas P, Sartor G, Villata S (editors). AI Approaches to the Complexity of Legal Systems. AICOL 2015, AICOL 2016, AICOL 2016, AICOL 2017, AICOL 2017, 2018, pp. 317-324.

[25] Maftuhah TS, Purwarianti A, Asnar YDW. Ontology modelling on legal document: Case study: Document of indonesian republic. Journal of Physics: Conference Series. International Conference on Electronics Representation and Algorithm (ICERA 2019); 2019; 1201 (1). doi:10.1088/1742-6596/1201/1/012061

[26] Markovich R. Understanding Hohfeld and formalizing legal rights: The Hohfeldian conceptions and their conditional consequences. Studia Logica 2020; 108 (1): 129-158. doi: /10.1007/s11225-019-09870-5

[27] Fernandez M, Overbeeke C, Sabou M, Motta E. What makes a good ontology? a case-study in fine-grained knowledge reuse. In: 4th Asian Conference on The Semantic Web 2009; Shanghai, China; 2009; pp. 61-75.

[28] González E, Piñeiro JD, Toledo J, Arnay R, Acosta L. An approach based on the ifcOWL ontology to support indoor navigation. Egyptian Informatics Journal 2021; 22 (1): 1-13. doi: 10.1016/j.eij.2020.02.008