

# 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 works such as [1]:

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

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

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

## 14 **2. Brief chronology of the COVID-19 in Spain (First wave)**

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

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

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

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

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

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

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

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

### 17 3. Related work: ontologies and legislation

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

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

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

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

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<sup>2</sup>Boletín Oficial del estado (Spain). BOE web site Orden 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]

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

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

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

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

#### 28 **4. Proposed ontology**

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

39 An important detail is the delimitation of the legislation to be covered by the ontology to a reduced  
40 set of Spanish legislation (the one related to the measures resulting from the pandemic episode) in a limited  
41 period of time. This allows us to approach the task of elaborating the ontology in a systematic way, without the

1 complications typical of the semi-automatic translation into a formal system of a field not specifically designed  
2 for it. Even this task would be more complicated given the characteristics of the Spanish language, where there  
3 is no strict word order in the syntactic structure. Even with these restrictions in mind, a series of tests were  
4 initially carried out with existing systems for the elaboration of ontologies from natural language. The FRED  
5 tool was used to evaluate the complexity and goodness of ontology translation, but was discarded because it  
6 offered a cumbersome structure (derived in large part from the complex nature of administrative language and  
7 the commented characteristics of the Spanish language) that was difficult to reuse and connect between the  
8 different concepts that appeared in the legislative documents.

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

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

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

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

36 The Statement class is enriched with a series of classes, object properties and data properties that act  
37 as metadata and facilitate searches within the ontology. First, the hasStatementCategoryType property allows  
38 to define one or several categories for the Statement class. To do this, several instances of a class called  
39 StatementCategoryType are defined. Examples are ChildrenCategoryType, UseOfPublicSpacesCategoryType  
40 and RestaurantOpeningCategoryType. Other information includes the phase of the epidemic episode to which  
41 the Statement relates and the date the provision takes effect. This allows you to filter searches and process  
42 updates of the various legal provisions. Therefore, the ontology includes the hasPhase and hasStartDate  
43 properties.

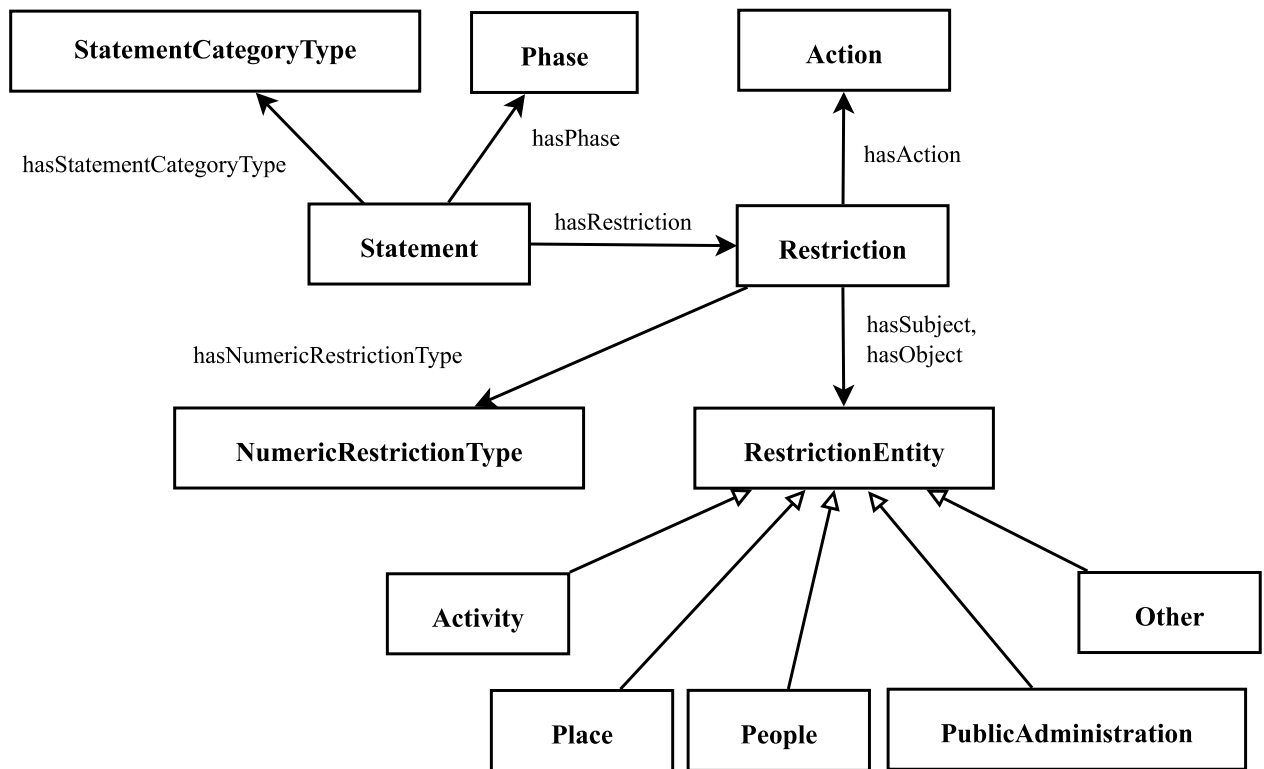


Figure 1. Main classes in the proposed ontology

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

$$hasRestriction^I \subseteq Statement^I x Restriction^I \quad (1)$$

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

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

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

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

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

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

$$Statement(ChildrenWalkingStatement)^I \quad (3)$$

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

**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

**Table 2.** Restrictions derived from legislation about children's walk (Spanish Official State Bulletin, 25<sup>th</sup> 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.



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

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

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

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

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

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

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

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

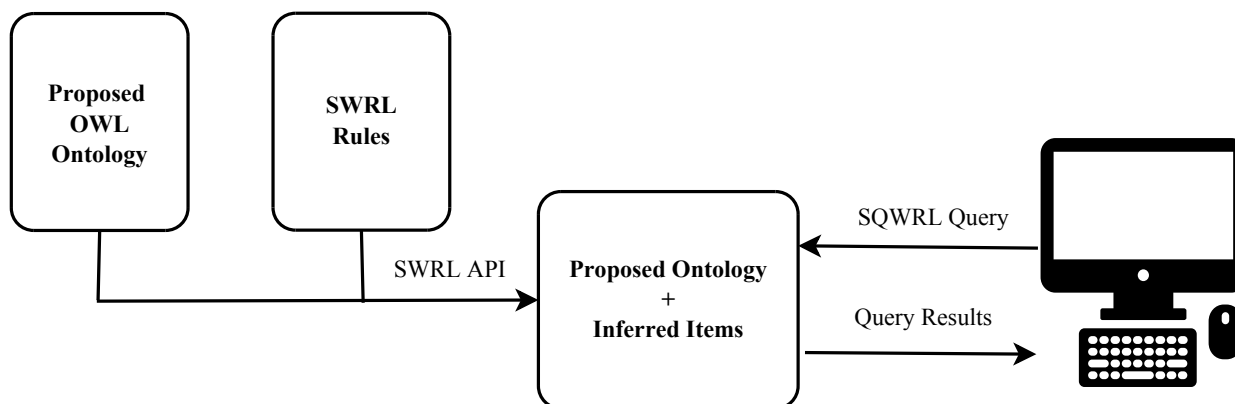


Figure 2. An example of flow for ontology inclusion in third-part applications

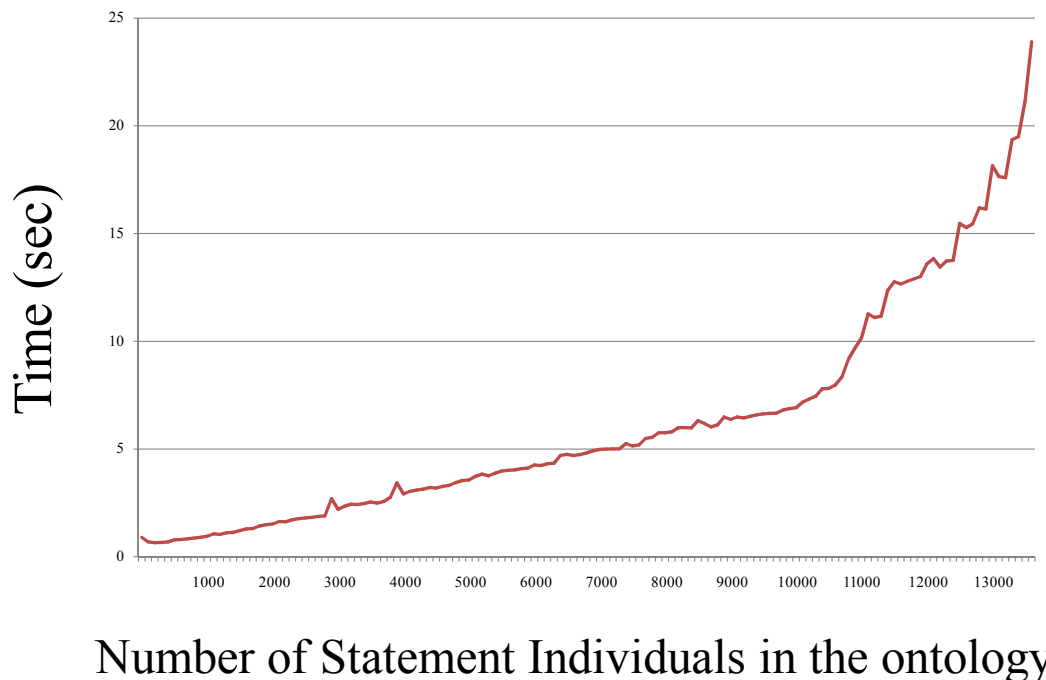
## 6. Proposal of implementation and test

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);
```

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



**Figure 3.** Results from SQWRL searches in Protégé.

1 the ontology, the author point to the results obtained by [27]. According to that work, it is not possible to  
 2 determine the best semantic content for a given domain from statistical information in the ontology.

3 Another test performed with the proposed ontology is the response time to a SQWRL search as the  
 4 number of instances of the Statement class in the ontology increases. For each individual, the relationships  
 5 and individuals have been defined according to Figure 1. The calculations have been carried out on the same  
 6 equipment used in other works by the author [28], that is an Intel®Core™ i7-2600 CPU @ 3,40 GHz processor,  
 7 8GB RAM. This allows a comparison of the simplicity/complexity of the proposed ontology with respect to  
 8 those works. The results are shown in Figure 3. As can be seen, for a case of 11,000 individuals in the Statement  
 9 class, the search time is just under 10 seconds. This result can be considered as satisfactory. One of the main  
 10 reasons for these measurements is the fact that the proposed ontology does not rely on third party sources.

## 11 7. Conclusions

12 In this article, the author provide an ontology-based design to efficiently describe the legal restrictions suffered  
 13 in Spain during the first-wave episode of the COVID-19 pandemic (March-June 2020). The proposed ontology is  
 14 based on a work unit called Statement that can be described as the set of elements of the legislation linked in a  
 15 semantic and temporal way. In addition to allowing a semantic search by the user, this configuration could allow

1 the study of the pandemic episode from various points of view, including legislative and social. The proposed  
 2 ontology can also serve as a basis for the implementation of ad hoc systems to verify if a certain situation in the  
 3 real world complies with the legal regulations expressed in the knowledge base. This type of structure makes it  
 4 possible to provide a knowledge base for computer applications without the need to recompile code, simply by  
 5 adding axioms to the ontology. In this sense, the proposed ontology is accessible through several implementation  
 6 perspectives. In this work it has been implemented using SWRL API and SQWRL queries.

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

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

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

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

## 22 **References**

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