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An Ontology for Digital Maritime Regulations

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ABSTRACT

The set of regulations that apply to ships and ports is already large and is increasing. Also, the long lifetime of ships, the different phases of ship operations and the large number of parties involved in the compliance and enforcement processes increase the need to make maritime regulations available in a machine-readable format. In this paper, we describe the process of making maritime regulations machine-readable and how this can improve the compliance and enforcement for ship and port actors. A maritime ontology has been defined and can be used by legislators when drafting new regulations. For ports, machine-readable regulations can be linked directly to the port procedures, and thus help port stakeholders to assess the impact of new regulations and trace their legislative origin. For ship operators, the maintenance and creation of Ship Management Systems can be simplified if machine-readable regulations are used to give an overview existing regulations.

1. Introduction

Commercial shipping is heavily regulated by a large number of international and national authorities in addition to the EU and local authorities in the ports. These authorities maintain a large and increasing number of maritime regulations that apply to ships and ports. These regulations are only to a very limited extent available in machine-readable and searchable formats, and no tools to support the creators to write new regulations and maintain existing regulations in a consistent way, exists. The result of this is that compliance with and enforcement of maritime regulations remain tedious processes with little digital support. This means that the complexity of the regulations and the dependencies between all the various stakeholders must be manually handled.

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The work reported in this paper was done as part of the EU-project e-Compliance. The main goal of the project was to create tools to help reduce the administrative burden on maritime stakeholders by using semantic technology and digital models to create and manage machine-readable regulations [(EU, 2016)]. The rest of this paper is organized as follows: Section 2 outlines the challenges with manual maritime regulations, Section 3 describes how the digitalization of maritime regulations are done, section 4 describes the application for ports and Section 5 describes how these regulations can be utilized by ship operators.

2. Challenges with Complex, Manual Regulations

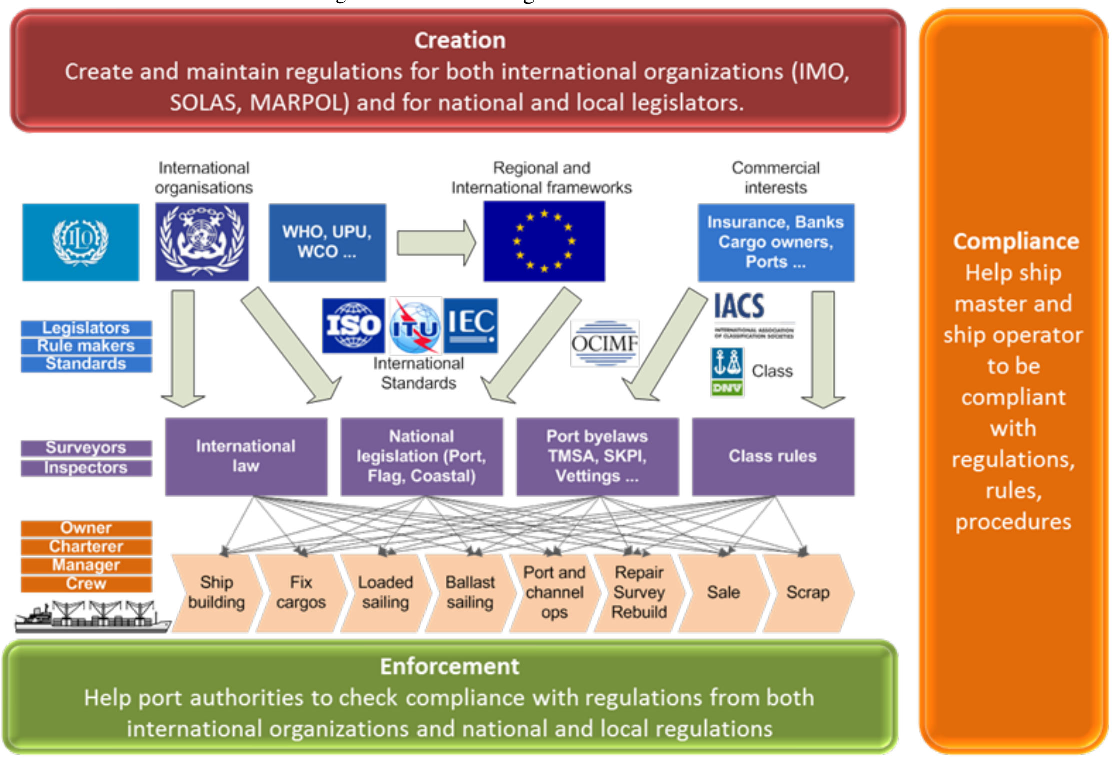
This section describes the complexity of maritime regulations and the challenges by not having the regulation text in a structured, digitalized format.

2.1. Complex Regulations

There are several factors that add to the complexity of maritime regulations and thus make their interpretation and compliance more difficult.

Maritime regulations are issued by several different organizations at different levels (international, supra-national, national, local), see Figure 1.

Figure 1: Maritime Regulations and Stake Holders



Maritime regulations are in many cases *related to each other*, for instance in the case where the EU issues a directive regulating maritime transport, which is subsequently implemented at the national level. Another example is the introduction of the ISM Code created by the IMO, and then implemented by each flag state, see Figure 2. Furthermore, each ISM company must create checklists and procedures in their Ship Management System (SMS) to comply with the ISM Code. For other regulations, for instance the ISPS Code issued by the IMO, the port authority may need to create port specific rules and procedures to comply with this regulation. An example of how port bye-laws are created in the Port of Barcelona is: First, the DG Energy and Transport builds the Directive 2005/65/EC (Regulation). Based on this, 'Puertos del Estado' (a public body dependent on Spanish Ministry of Development), builds the Spanish law (Port bye-law) for regulating the port procedures (BOE, 2011). This law is then the base for designing the port calls procedure PIDE (Port Calls integrated procedure) (PIDE, 2016). The Barcelona Port Authority implements this procedure, but some topics change due to several reasons (Terminal operator requirements, etc.). At last, each ship agent builds a list of formalities to be performed by the vessel crew within the vessel arrival procedure. This checklist is based on the procedure, and each ship agent adds items due to internal needs (they can change the number of hours before submitting a document, request the vessel crew to phone the ship agent, etc.).

Further, the *applicability* of maritime regulations is complex in that it can depend on several factors, for instance the ship type, keel laid date, flag state, crew nationality, type of voyage, departure and destination port, geographical areas, port state, weather conditions, ice conditions, average temperatures and a combination of these. All these different applicability types must be viewed as a whole to get the correct regulations and paragraphs of a regulation that must be complied with in a certain situation.

Law text is generally complex with long, complex sentences, multiple exceptions and text written as lists where there can be either a meaning of 'OR' or 'AND' between each item.

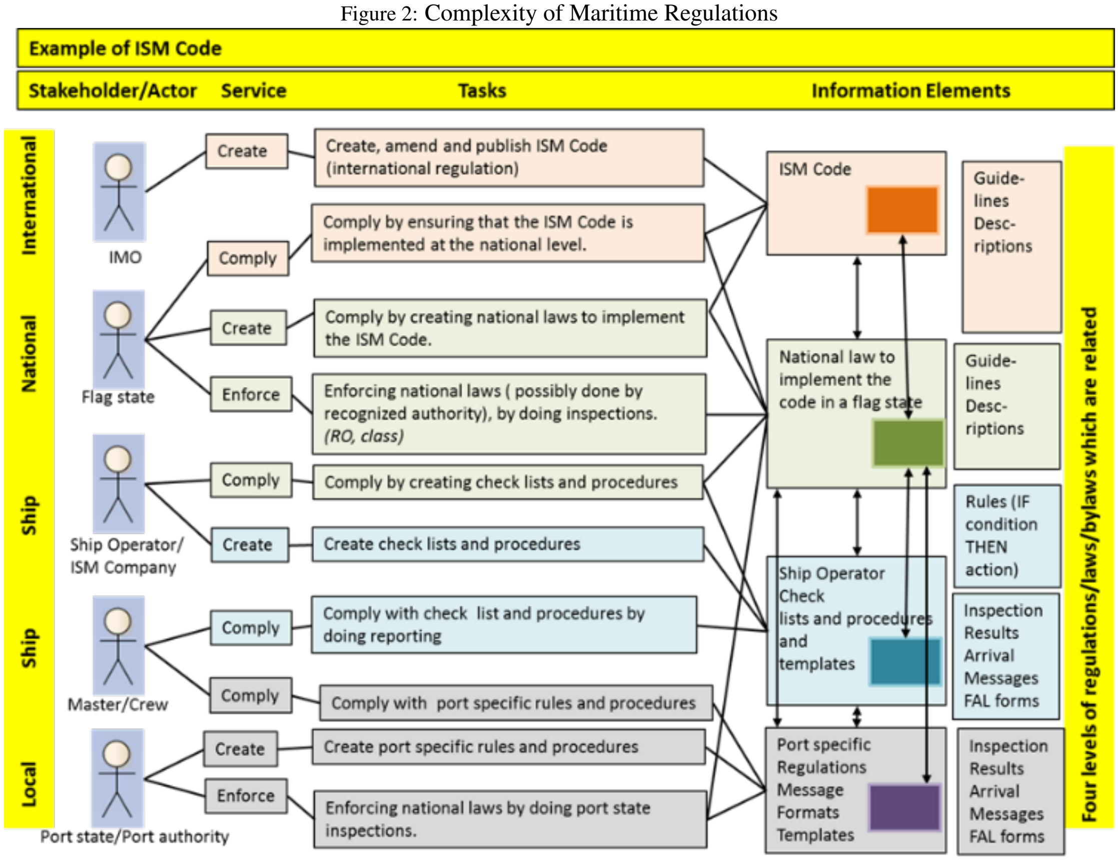
Sometimes things are *intentionally left open or unclear* if agreement is not reached. In addition, errors may happen during the law creation or updating processes, for instance that some paragraphs that were meant to be invalidated are not invalidated.

Regulation text has several *links to other sections* in the same regulation and also to other regulations issued by different organizations. This makes the interpretation of the regulation text a complex process, since the reader also needs to be sure that the correct version of the text is found.

There is a *large number* of regulations, and the number of regulations is increasing. This is because regulations are very seldom invalidated; instead new regulations are introduced to cover new situations and also to solve inconsistencies, misunderstandings and ambiguities in existing regulations.

Ships have long lifetime, meaning that new rules may apply to the ship over its whole lifetime. The 'grandfathering' principle means that regulations hardly can be deleted, since they may still be applicable for older ships. For instance, amendments to SOLAS and MARPOL related to the structure of a ship shall apply only to ships which can be considered to be built on or after the date on which the amendment enters into force. Thus,

Figure 2: Complexity of Maritime Regulations



previous versions of the regulation text must be 'kept alive' to maintain the correct text for older ships.

Regulations *cover all different phases of shipping*, both design, build, operation and transportation, which means that the domain is very large with lot of different concepts.

The Force Majeure clause adds complexity to the interpretation of the regulation text since this introduces a possible exception for all regulations.

New regulations may have an *unclear relation to existing regulations*, for instance how the new Polar Code (IMO, 2016) relates to the United Nations Convention on the Law of the Sea (UN, 2016). This ensures the 'freedom of the seas' -concept for other nations in a coast state's water. One question is whether the Polar Code will restrict the sea traffic more than what is ensured in the Law of the Sea, since by accepting the Polar Code, a flag state will reduce their influence compared to what is stated in the Law of the Sea (Jensen, 2016).

The *definitions* used in a regulation text contain a lot of information that must be considered during the interpretation of the whole text. This makes the text more fragmented as a lot of information that is spread out over different chapters and different regulations must be considered at the same time.

The fact that maritime regulations are very complex leads to problems for all stakeholders involved in maritime transport, both for regulation creators, for ship operators, ship managers, captains, ship agents and for port authorities.

2.2. *Regulation Creators*

For the international, national and local authorities, writing new regulation text and maintaining existing text with respect to consistency, completeness and correct use of terms and ensuring correct linking to other regulations, is very challenging. It is difficult to find the exact definition of a term, and it is difficult to know which term to use in a certain case. The same term can be used for two different 'things', for instance as in SOLAS, where both 'bulkcarrier' and 'bulk carrier' is used, but with different definitions (in Chapter II-1, IX, and XII). Also, two terms can be introduced to denote the same concept, for instance 'fishing boat' and 'fishing vessel'.

2.3. *Collaboration*

One challenge with having complex and non-machine readable regulations is that the connection between the makers of the law with those who need to enforce or obey it is not supported through an electronic system, meaning that the changes must be manually published to the users of the law. The same goes for International Safety Management code companies. They are not automatically aware of updates on regulatory changes, and the information is not filtered by relevance for them (for example, ship or cargo types and geographic regions). This makes it more difficult for the practitioners to update their processes and internal procedures to ensure compliance.

Another challenge is for the ship crew to know the actual rules that are valid in a port, since the local bye-laws and the mandatory reporting requirements vary from port to port. Without having computer-readable 'rules' that contain the requirements of the bye-laws, it is a manual and labour intensive process for the ship agent to keep track of the requirements and to alert the captain and the crew about these and also about the cases where the requirements are not met.

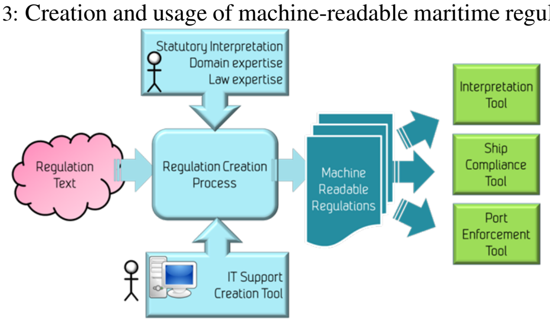
Further, with no machine-readable regulations, ports are not able to publish regulations and report templates directly to ship systems so that the ship systems can pick these up and automatically initiate the reporting and compliance-checking process.

From a business perspective, shipping companies spend a large amount of resources collecting new and updated regulations each year. In addition to the cost, they often remain unsure that their system is up to date and that authorities in different ports do agree with their interpretation of the regulations.

3. Creation and Maintenance of Machine Readable Maritime Regulations

This section gives an overview of how the machine readable regulations are created from plain regulation text and how this supports the interpretation and searching of the regulation text.

Figure 3: Creation and usage of machine-readable maritime regulations



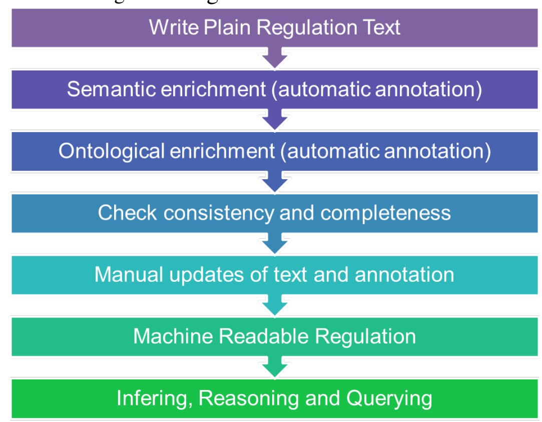
The writing and maintenance of machine-readable maritime regulations require domain expertise, legal expertise and also knowledge of how the text can be interpreted, Figure 3. The e-Compliance project developed a prototype for an ICT Creation tool where new regulations can be written, existing regulations can be uploaded, manual and automatic annotation of the text can be done, consistency is checked, plain text is stored according to a maritime ontology, interpretation of terms, definitions and links to related and similar regulations are readily available, and search capabilities exist.

3.1. The Regulation Creation Process

Central to our approach to creating machine-readable regulations is the concept of a 'Rule'. In this context, a Rule is a data structure consisting of three parts:

- The 'Target', capturing who or what the regulation applies to (typically a type of ship or a person);
- The 'Context', describing the conditions under which the regulation is applicable for example geographical location, weather or currently performed activity;

Figure 4: Regulation Creation Process



- The 'Requirement', capturing what is demanded of the Target in order to be compliant with the regulation, for example the submission of a report or the availability of a piece of equipment.

We capture the content of a regulation by creating a Rule instance and storing it in a specifically created maritime ontology, see Figure 5. In the Creation Tool, we mainly focused on describing the ship classes to which a given regulation applies.

The steps in the process of creating machine-readable regulations are shown in Figure 4. The first step is to automatically annotate the raw regulation text using specifically created semantic tools. This process serves two purposes:

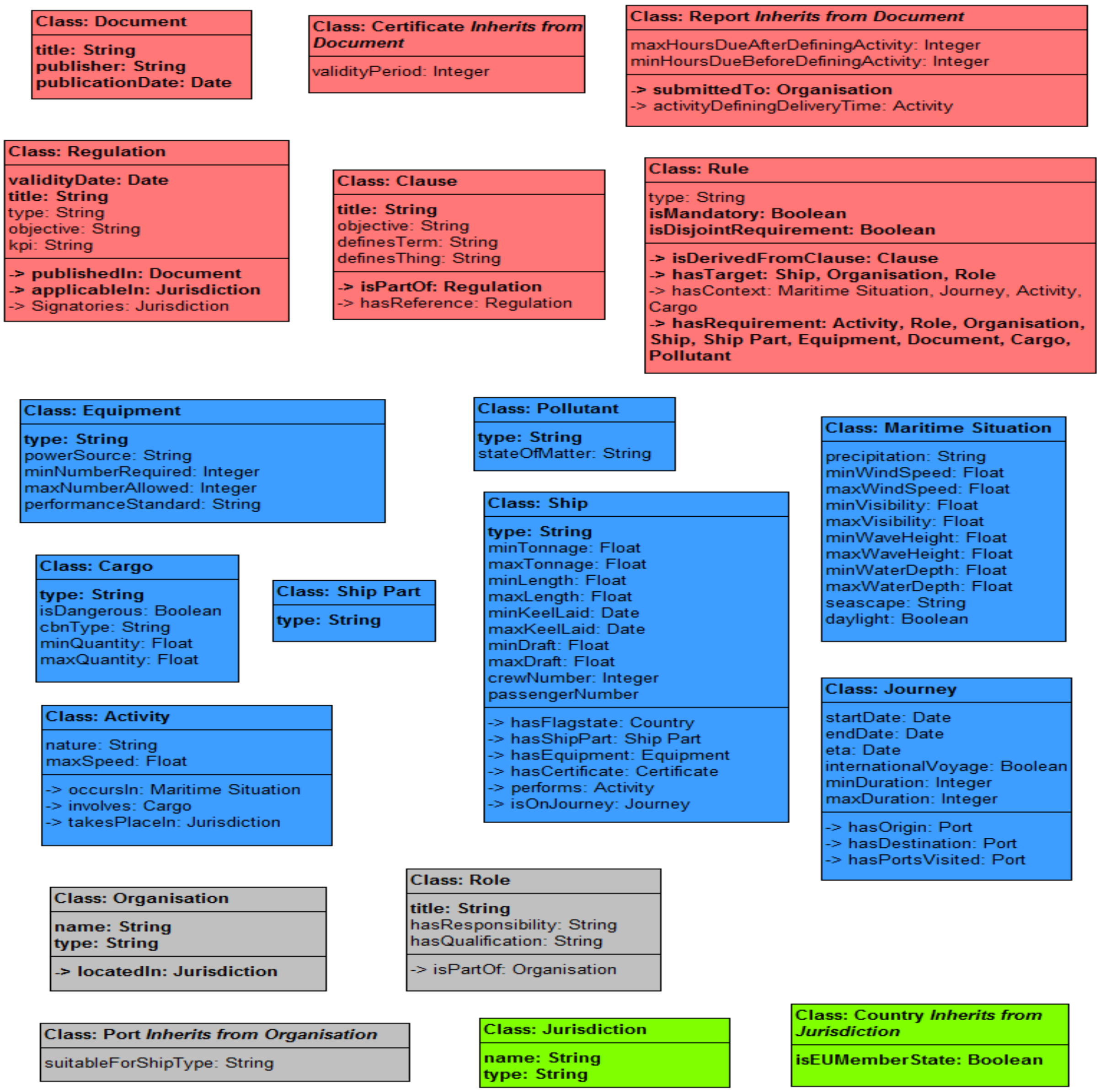
- To check for a consistent use of terms. This step is based on the e-Compliance thesaurus described in [9] and a specifically created, publicly available reference vocabulary for the maritime domain.
- To extract a Rule to capture the content of the regulation text.

The outputs of this annotation process are then checked by the author; if necessary, he or she will adjust both the text and the suggested Rule. Once satisfied, the user can save the Rule in the e-Compliance ontology, thus creating a machine-readable version of the regulation, capturing in particular the set of ships to which it applies. Subsequently, standard semantic technology (so-called 'Reasoners') can be used to decide which regulations apply to a given vessel. The steps above will be explained in more detail in the following sections.

3.2. Semantic and Ontological Enrichment

The automatic annotation of raw regulation text is done using the specialist semantic tool Luxid. Luxid annotation services are based on Text Mining processes for extracting and analysing large volumes of unstructured text content in order to discover enriched relevant information in a machine-readable output format. This approach requires the creation of specific resources (called Skill Cartridge) for terminology and component hierarchies in the maritime domain.

Figure 5: Maritime Ontology Classes



For the purpose of the e-Compliance project, two dedicated Skill Cartridges was developed, a first one based on the e-Compliance thesaurus and a second one that extracts the instances (Rules and Entities) with their properties for each object modelled. The regulations are enriched thanks to the relevant pieces of information that are modelled in the Skill Cartridges, mainly:

- Publication information (for instance authority, instrument, publication date and amendments) and document parts (for instance title, paragraphs and notes)
- Scope of the rule (for instance the geographical area concerned, the application date, the ship types affected, its applicability in new or existing vessels, the conditions)
- The ensued restrictions and/or requirements (that is, reporting formalities and certificates, declaring party).

The result of the extraction process is a suggested Rule that captures the content of the regulation (in particular the set of ships it applies to) as well as information on whether 'correct' terms (as defined by the thesaurus) have been used. An example of such an output (for a fictitious regulation) is shown in Figure 8. Note that in the regulation text, the term 'life raft' was used, whereas the 'official' term (called the Preferred Label) is 'liferaft'. The thesaurus contains about 1,500 maritime terms, with labels in English, French and Spanish. The output of the annotation process is manually checked by the user; if required, both the raw text and the suggested Rule can be updated at this stage.

Figure 6: Target ship class as seen in Protégé

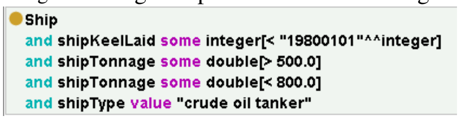


Figure 7: Target ship class extracted from a MARPOL regulation

3.3. *Encoding of Maritime Regulations*

The set of ships to which a regulation applies is stored as a target ship class in the e-Compliance ontology, see class Rule in Figure 5. These classes are specified by a set of ship-specific variables. The variables currently used includes *ship type, tonnage, length, draft, passenger number and keel laid date*. It is easy to extend this list, but these variables are sufficient to demonstrate the concept.

A target ship class is defined by restricting the ranges of these variables. As an example, the fictitious regulation used in Figure 8 imposes the following restrictions on its target ship class:

- Ship Type = 'oil tanker'
- 500 GT < Tonnage < 800 GT
- Keel Laid Date > 19800101

For this extremely simple example, the target ship class can be fully automatically extracted from the regulation text using the Luxid tool, see Section 2.2. The resulting class in the ontology is shown in Figure 6 as a screenshot of Protégé, a popular ontology editor. Note that the ship type has automatically been changed to 'crude oil tanker', which is the preferred label in the e-Compliance thesaurus.

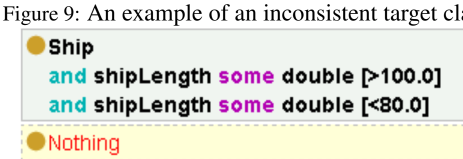
In general, target ship classes of real maritime regulations are more complicated than the over-simplified example used above. However, any relation of sets can readily be constructed using the operators union (∪), intersection (∩) and complement (¬). Thus, let us consider the following example from MARPOL MARPOL (2016), Figure 10.

The target ship class is given as the union of the two sets 'Ships ≥ 400 GT' and 'Oil tankers ≥ 150 GT'. The resulting target ship class is modelled in Protégé as shown in Figure 7. In practice, restrictions on target ship classes are frequently spread out over different parts of a regulatory instrument. For example, SOLAS Ch.1 Reg.4 UN (2016) contains the subtitle *'Applicable for all ships from 1980-05-25'*, which is not repeated in the actual regulatory text. In addition, there are regulations that specify applicability and exemptions for the rest of the chapter or indeed the rest of the document. One of the main purposes of the Creation Tool is to help users keep track of these restrictions; once they have been added to the ontology, the Creation

Figure 8: Example of an enriched regulation 'All oil tankers bigger than 500 GT but smaller than 800 GT and built before 1 January 1980 must have at least 4 life rafts'.

Tool will be able to collect and consolidate all applicable restrictions to the target ship class of a given regulation. This approach relies on creating a hierarchical model of the document in RDF, see Section 3.5.

Figure 9: An example of an inconsistent target class



The main advantage of using an ontology to capture the content of maritime regulations is that readily-available software tools called 'Reasoners' can be used to check the consistency of the extracted target ship classes and indeed of the ontology as a whole. If the user tries to implement inconsistent restrictions on a class, the system will give a warning. Figure 9 shows a simple example of an inconsistent target class shown in Protégé. Note that after invoking the Reasoner, the class is shown as equivalent to 'Nothing' (i.e. the empty set), indicating that the imposed restrictions cannot be fulfilled.

3.4. *Semantic Search*

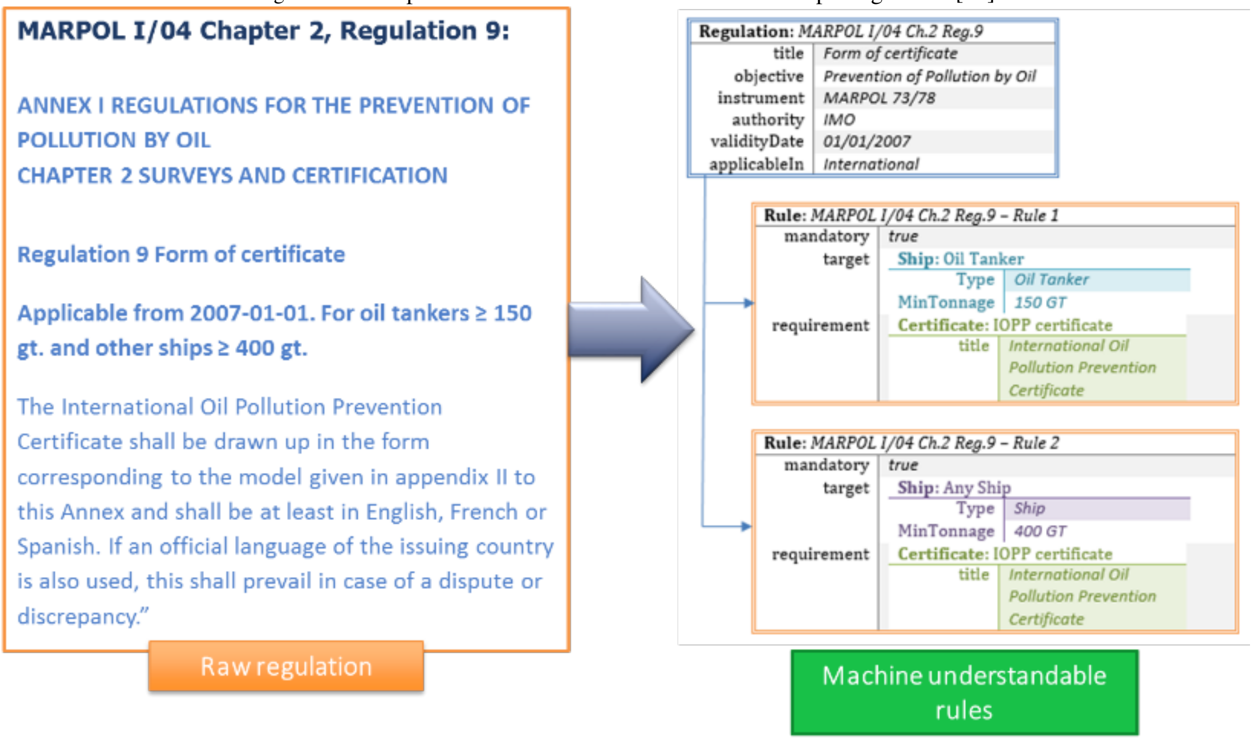
Assume we have a concrete instance of a vessel, how can we find the regulations that apply to this ship? To answer this question, we first create an 'instance' of a ship in the ontology, specifying the values of the parameters, see Figure 11.

We then simply invoke a Reasoner to retrieve all target ship classes of which this instance is a member. The regulations that gave rise to these classes are the ones that apply to the ship instance. For the given example, this includes the MARPOL regulation in Figure 7, but not the (fictitious) example in Figure 8.

3.5. *Implementation*

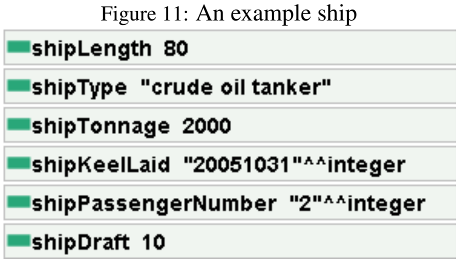
This section describes the choices made regarding storage formats of the machine readable regulations, including the means by which documents are logically structured, how metadata

Figure 10: Example of structured and machine-readable output regulation [13]



and linkages are systematically added using technologies originating in the semantic web, and how the Creation Tool and other services access such information. We have taken our inspiration from efforts made by legislation.gov.uk to make UK primary legislation available as linked data over machine accessible web interfaces. In that case, legal instruments are manifested as XML documents according to an XSD schema, then annotated with metadata elements originating in linked data standards. We take this two stages further: first, by expressing the underlying data model as a semantic web graph; and second, by including links between textual elements in legal instruments, and the OWL classes which unambiguously identify them within a maritime domain ontology.

Figure 11: An example ship



3.5.1. Storing Machine Readable Regulation Text

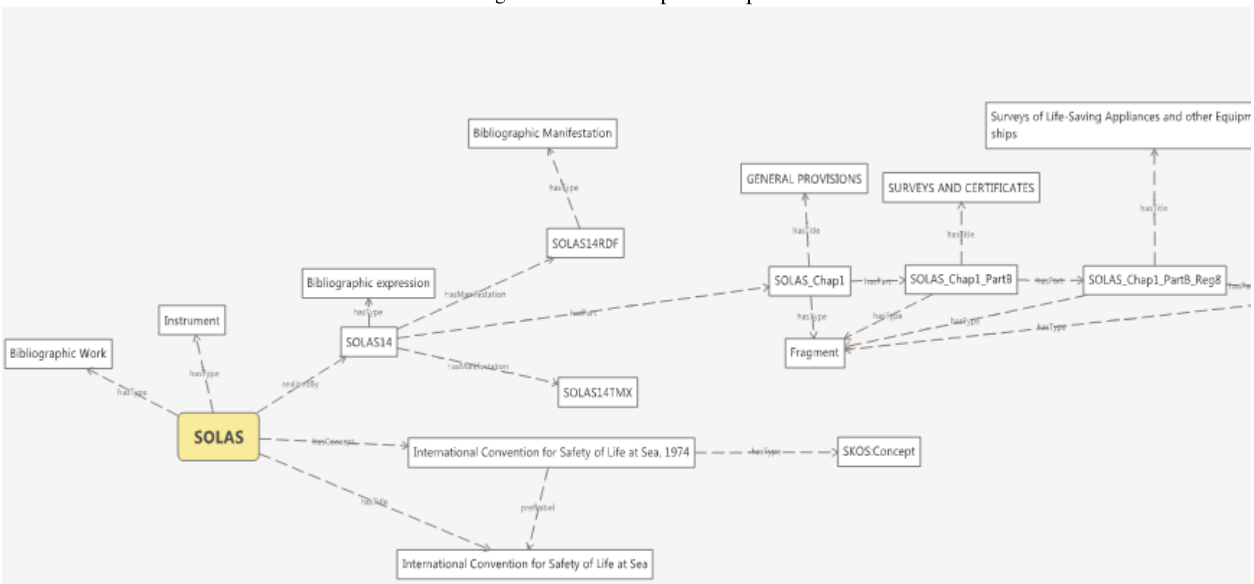
For storage and retrieval, ontology entities and legislative documents are converted to RDF and stored in a triple store. The stored RDF graph adheres to OWL and makes use of the Dublin Core, Metalex, OrderedListOntology and SKOS. For prototyping, these triples have been stored in an in-memory database supplied by Apache Jena, and enterprise graph or triple stores with transactional features, such as Giraph, Neo4J, or Apache Jena TDB/Fuseki are suitable for production usage. The resultant RDF permits multiple use cases and extensions, some of which are used directly by the e-Compliance Creation Tool, but all are relevant to the structured and consistent editing, distribution, browsing, linking and reuse of maritime legislation. In particular:

- Queries may be issued against the full knowledge graph using SPARQL[6] through RESTful interfaces to CRUD operations, for which we provide an example below;
- 'Missing truths' and contradictions are deduced using OWL reasoners (see also Section 3.3) and the knowledge base may be further enhanced with SWRL rules; semantic consistency of the underlying data structure can be guaranteed (e.g. Metalex Bibliographic Expressions must be a realisation of exactly one Bibliographic Work);
- The data schema may be readily linked to other online repositories of relevant linked data (e.g. legislation.gov.uk publishes all UK statutes as XML containing semantic metadata) using semantic web tools.

Structured regulation text is input from the Creation Tool via a simple RESTful interface; that abstracts the specifics of

[6]Strictly speaking, we use ARQ, the Jena implementation of a SPARQL 1.1 compatible RDF query language, which includes the capability to conduct full text searches on nodes.

Figure 12: RDF Graph Example



RDF document interactions manipulating RDF-XML triplets, to domain specific actions. The service handles issuance and enforcement of structured, unique identifiers for all entities, and these URI 'handles' on RDF nodes may be shared across services. As a design choice, RDF triples are considered immutable so that URIs remain consistent (documents are viewed as essentially static content, so immutability of the metalex: Bibliographic Expression (the document version) guarantees that references to a particular manifestation of that document stored as a static web resource remain valid. As an example of the prototype functionality permitted by the RDF representation, below is a SPARQL query showing how a concrete document representation can be reconstructed from its graph representation.

The code snippet in Figure 13 shows a SPARQL 1.1 query conducting a depth-first traversal of an RDF document tree for a SOLAS Chapter 14 expression. It utilizes the imodoc (IMO documents), olo (OrderedListOntology) and list (ARQ list) ontology namespaces and reconstructs the sub-document nesting and branch ordering (e.g. a document hierarchy of Chapters - Sections - Paragraphs) for an arbitrary document type. After reconstructing a table containing the URI of the content, its depth within the master document, order and formatting information (i.e. should this be formatted as a Chapter, Section, BulletedList, etc., where options exist within the namespace of the document root, imodoc: SOLAS_1_14). A subset of the underlying RDF graph is shown in Figure 12. The full version is available from the authors on request. Ontology enhancements derived by semantic consolidation rules applied in Section 3.3 are logically stored in RDF, both within the Jena triple store and as OWL RDF/XML text files.

3.5.2. User Interface for Creating Machine Readable Regulations

Figure 14 shows a screen from the Creation Tool where a regulation text is interpreted and the annotated terms and the target are found and displayed. The following describes some basic steps of the graphical user interface available to the regulation creator. The plain regulation is entered by the user. After the user has written the plain text, he can click the 'Check Terms'-button. Then, the semantically annotated regulation text is displayed. In the example from Figure 14, the terms 'Oil tankers', 'reporting', 'oil' and "coastal waters" are found. Also, it is shown that 'Crude oil tanker' should be used instead of 'Oil tanker' since this is the preferred label in the e-Compliance maritime thesaurus.

The target is displayed, if found. In Figure 14, 'Crude Oil Tanker' is the target of the Rule, which further means that this regulation applies to all ships of type Crude Oil Tanker. The user then is free to update the regulation text more correctly and precisely reflect the meaning of the regulation. In another screen, the user can enter tags (meta-data) to the regulation to manually enrich the text. Examples of these are:

- The Regulation Title: The text that constitutes the title of a regulation.
- The Regulation Type, for instance certificate, procedure, checklist, technical specification, operational specification, functional requirement or report specification.
- Regulation KPI: KPIs can be added to be able to measure the consequences of introducing a new regulation, both in terms of unwanted and wanted effects, and also to improve the searching of the regulations based on the meta data value. For instance, for the ISM Code, the following KPIs may be relevant to check compliance: *Flawless Port state control performance, Lost Time Injury Frequency,*

Health and Safety deficiencies, Lost Time sickness Frequency, Crew planning, HR deficiencies, Releases of substances as defined by MARPOL, Contained spills, Environmental deficiencies, Passenger injury ratio, Port state control detention, Vetting deficiencies, Condition of class, Failure of critical equipment and systems, Fire and explosions and Port state control deficiency ratio.

- Invalidate: Regulations can be invalidated after being confirmed, instead of being deleted.
- Regulation Hierarchy: Regulation text is structured in a hierarchy.

Figure 13: SPARQL Snippet

```
String prefix = "prefix rdf: <" + RDF.getURI()
+ ">\n" +
"prefix owl: <" + OWL.getURI() + ">\n" +
"prefix imodoc: <" +IMO_DOC_NS + ">\n" +
"prefix olo: <"+ORDERED_LIST_NS+">\n"+
"prefix list: <" + ARQ_LIST + ">\n";
showQuery( model, prefix +
"SELECT ?item ?depth ?idx ?section_type
WHERE {  ?slot olo:item ?item. ?slot olo:index
?idx. {SELECT ?item" + "
(count(?intermediate)-1 as ?depth)
WHERE {imodoc:SOLAS_1_14
(imodoc:contains/olo:slot/olo:item)*
?intermediate . ?intermediate
(imodoc:contains/olo:slot/olo:item)* ?item
?format_type .} group by ?item order by ?depth
}" + " }
ORDER BY ?depth ?idx");
```

After the user has completed the manual update of the regulation text, he makes the regulation permanent, and it is stored in the RDF-XML graph.

Also, checking of specific terms can be done in another user interface where the user enters just the term he wants to check, and then the broader term and preferred term are found from the thesaurus (the SKOS terms) and displayed to the user.

When updating the regulation text, the user can ask the system to display a set of possible ship types to use as the target of the rule. Then, the user can select one or more of these, and he can add his own definitions of ship types to be used as target of the rule.

The user can search for similar regulations using Luxid services. An extension to this is to allow the user to check the regulation for possible inconsistencies and incompleteness using the ontology services, not only semantic queries.

The objective of the regulation is not entered manually by the user, since this can be found in the RDF-XML-graph: The objective of the regulation is often found in the regulation text itself. This objective is then inherited by the sub-regulations of the regulation. This is implemented in the subject field of the linked data, where the 10 most used SKOS terms used in the plain regulation text are fetched from the RDF-XML graph representing the text. Lists of paragraphs in the regulation text are handled by letting the user specify either 'AND' or 'OR' between each of the sibling regulation paragraphs. The Amendment Date is automatically set by the Creation Tool to be the date when the regulation was last updated. Validity date, expiration date and availability date need not be manually added by the user, since these dates are found by the semantic annotation.

The user interface also provides links from one regulation to another regulation to increase the readability and simplify the maintenance of the text.

4. Digital Maritime Regulations in Ports

This section describes some of the advantages and new functionalities that can be made available to the port stakeholders when they ensure the compliance with various maritime regulations and how this supports the enforcement done by the ports. Specifically, a Port Community System (PCS) can make use of machine-readable maritime regulations to make the ship reporting easier and the follow-up better. In the following, we call this add-on to the Port Community System 'The e-Compliance System'.

The Port System will enable a port or ship agent to publish regulations and report templates in a machine-readable format. Such documents could be picked up by the e-Compliance system and specifically tailored to the needs of a ship, automatically initiating the reporting and compliance-checking process when required. This would be straightforward in some cases - for example, when extracting a ship?s 'static' data such as its identity number, name and tonnage.

The port system extended with functionalities from e-Compliance is used by the ship agent in the port to simplify the communication with the ship captain about which reports need to be submitted and when. The port system is composed of three subsystems:

- Rule Authoring GUI: Web application that enables the port authorities to manage the reporting rules.
- Rule Compliance System: Database where the previous reporting rules are stored. It is also composed of a set of services to fetch the reporting rules dependent on different conditions.
- Reporting Gateway: Web application that enables the ship master and sometimes ship agents to consult the rules and execute them.

The port authority will represent the reporting rules, that is, the tasks, related to the vessel arrival procedure to comply in a port, which are grouped by vessel type (procedure for container vessels, cruisers, etc.). Optionally, the ship agents can override these reporting rules and tasks for a vessel type in a port by adding internal requirements (send an email with a specific information, etc.), or he can set reporting rules by vessel instead of vessel type for covering extreme exceptions. Each reporting rule can be subject to conditions such as Draft mean, Cargo amount, Crew number, Deadweight, Length over All, Gross tonnage, Passengers number, Dangerous goods or Pollutant. It indicates:

- When the rule must be performed (for instance 24 hours before arrival)

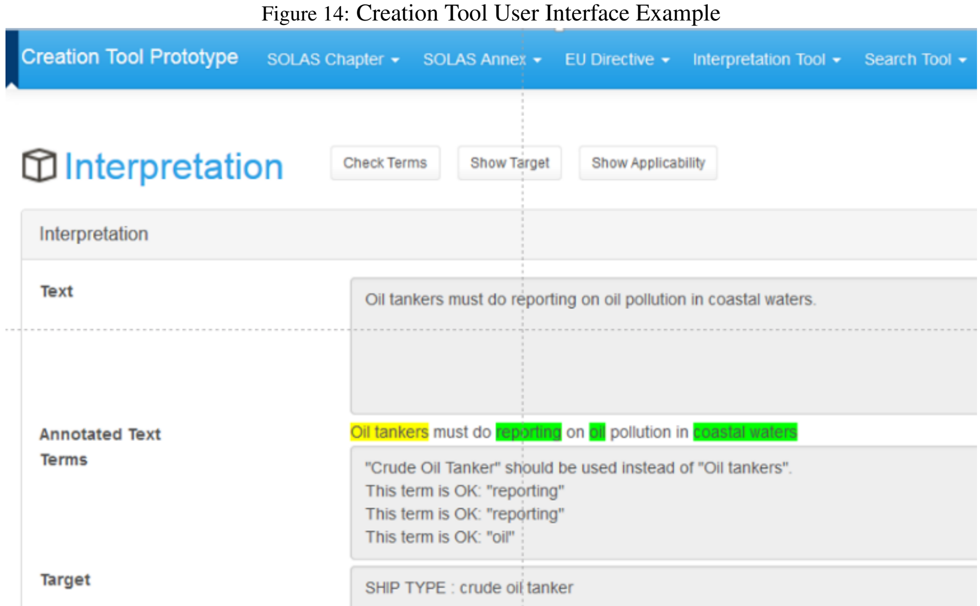


Figure 14: Creation Tool User Interface Example

- Site where the rule must be performed (for instance in Port waters).

This system will enable the vessel crew to access the system to query the reporting rules to comply with when berthing in a port, and they can use it for submitting the required information for each reporting rule.

5. Digital Maritime Regulations for Ship Operators

This section describes some of the advantages and new functionalities that can be made available to the ship stakeholders to ensure the compliance with various maritime regulations. The Ship Management System (SMS) can be used as a regulatory enforcement tool for ship operators as described in the following. A new regulation imposed from a regulation creator (for instance IMO) is transformed to a machine-readable format and the SMS database is updated both onshore and at sea. All the formalities are amended and at last, alerts are sent to designated users to alter their workflow or procedures.

The Safety Management System (SMS) is an important component of the International safety management (ISM) code. The SMS consists of regulations implemented by the quality department of a shipping company in order to ensure safety of the ship and secure marine environment at sea. The SMS is a fully controlled top tier document management system which translates regulations into procedures setting a workflow of safety rules to be followed by marine staff.

The SMS is a dynamic document constantly revised with new regulations. Maintenance and update of the system adds complexity and administrative cost to the company. Dealing with aforementioned challenges, the e-Compliance project has developed an innovative SMS assistant IT solution where the SMS policy manual is structured in a hierarchical multi-level document breakdown, including revision history and appropriate meta-data, such as effective date, issue date, updated references and forms. This means the new system does not only facilitate navigation for designated users but also ease tracking and implementation of changes vertically and horizontally to the entire system. Updates are managed with minimum of human intervention in an effective, automated and confidential procedural mechanism.

Once a new amendment is published and translated into a regulation repository, the appropriate build-in e-Compliance mechanism is triggered, informing accordingly all involved bodies, altering related statutory forms and changing templates either in content or in task rules, consequently updating safety procedures. Finally, the rule compliance engine tool alerts authorized users for any case of data inconsistency or action required. The procedure of updating the SMS when a new statutory regulation is imposed.

The e-Compliance assistant tool comes in an on-shore and an on-board version. As far as the Safety Management System Assistant on-board version is concerned, the SMS manual, formalities, static and operational data are stored in an on-board database and some of these data are exchanged with the office version. The synchronisation process makes minimal use of the limited internet connectivity on the ship, while maintaining a high level of consistency with the shipping company databases (on-shore) and other deployments of e-Compliance systems on other ships.

The novelty is that the tool may be used from any ship whether it has its own on-board application or not. Existing or new formalities designed by commercial standard tools like Microsoft Excel, Word, PDF forms, Google forms or InfoPath may be used immediately without any change. The tool retrieves and stores only the filled in data, assigns them to attributes and consequently exchanges them with office with minimum communication volume and cost.

6. Conclusions

The work done on machine-readable maritime regulations shows that this is a promising tool to increase the consistency of regulations and to support the compliance and enforcement done by ship and port actors. We have made great use of already existing semantic tools to extract initial meaning out of the text. However, more work must be done to be able to handle requirements, contexts and exceptions in the regulation text, and also to handle huge amount of regulation text and the relations between different texts.

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References

BOE, (2011). Orden fom/1194/2011, de 29 de abril, por la que se regula el procedimiento integrado de escala de buques en los puertos de interés general.
URL: http://www.boe.es/diario-boe/txt.php?id=BOE-A-2011-8339

EU, (2016). e-compliance-project.
URL: http://www.e-compliance-project.eu/

IMO, (2016). International maritime organization.
URL: http://www.imo.org/en/MediaCentre/HotTopics/polar/Pages/defaul

Jensen, Ø., (2016). The international code for ships operating in polar waters: Finalization, adoption and law of the sea implications. Arctic Review on Law and Politics 7 (1), 60–82.

MARPOL, (2016). International convention for the prevention of pollution from ships.
URL: http://www.imo.org/en/About/Conventions/ListOfConventions/Pag

PIDE, (2016). Barcelona port authority.
URL: http://www.portdebarcelona.cat/cntmng/d/d/workspace/SpacesSto

SOLAS, (1974). International convention for the safety of life at sea.
URL: http://www.imo.org/en/About/Conventions/ListOfConventions/Pag

UN, (2016). United nations convention on the law of the sea.
URL: http://www.un.org/depts/los/convention-agreements/texts/unclo