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AN ONTOLOGY-BASED APPROACH FOR DEVELOPING OFFSHORE AND ONSHORE PROCESS EQUIPMENT INSPECTION KNOWLEDGE BASE

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ABSTRACT

A collection of inspection results is an essential input in assessing and managing the technical integrity of offshore and onshore process equipment. The inspection results enable the current condition of the equipment, the type of damage mechanism, and the severity and location of the degradation to be investigated. Typically, the inspection results are documented in a text-format report and stored in a conventional data repository. Conventional inspection data storage has drawbacks in terms of the sharing, exchange, and retrieval of information within an inspection knowledge domain, due to the lack of knowledge representation. This study proposes an ontology-based approach for developing an inspection knowledge base, in order to improve the degree of retrieval, distribution, and administration of inspection results. Ontology provides a semantic structure and relations for concepts in the inspection knowledge domain, which facilitate semantic search capability and enable increased utilization, enhanced communication and improved exchange of inspection information. A case study of a static equipment inspection is shown, to demonstrate the application of an ontology-based approach in facilitating data and information retrieval from an inspection knowledge base.

Keywords: inspection knowledge domain, knowledge retrieval, pressure vessel, ontology, semantic model

INTRODUCTION

Damage mechanisms (e.g., corrosion, cracking, fatigue, erosion, etc.) impair the technical integrity of equipment in offshore and onshore oil and gas production and processing systems [1, 2]. Equipment failure is likely to occur if the corresponding damage mechanisms are not controlled and mitigated. Regular inspection is normally performed to manage the risk of failure (RoF) and to ensure the equipment is fit-for-service [3]. Inspection generates information regarding the actual condition of the equipment, which is then used to estimate the extent of degradation of the equipment and to decide the appropriate mitigation action (e.g., maintenance, modification, or replacement), to prevent impending equipment failure [4]. Additionally, a collection of past inspection results (i.e., inspection history) is one of the critical inputs to assess equipment RoF [4], as it can indicate the current condition of the equipment, the types of damage mechanism, and the severities and locations of the degradations [5]. A technical integrity management program, such as risk-based inspection (RBI), depends heavily on the availability of inspection history data to optimize inspection and maintenance planning and scheduling [2].

Inspection results are normally recorded and documented in a text-format report, which is then stored in a conventional data repository [6]. However, this approach has some limitations. First, it is difficult to make queries and retrieve specific information from the repository, especially when a large volume of data is involved [7]. This means that the traditional inspection data repository is static and presents discrete data without showing relations among them [8]. This limitation creates a barrier to the reuse of past inspection results, especially during the risk assessment process. Second, text-format reports and traditional databases do not support knowledge-sharing activities [9], which makes collaboration among stakeholders in the inspection-related activities challenging [10]. There is a lack of formal knowledge representation, which creates difficulties in building a shared and common understanding of the inspection-related domain that facilitates ease of communication between people in various disciplines [11]. The ability to communicate and collaborate effectively is crucial, considering the multi-disciplinary nature of inspection-related activities.

The objective of this paper is to tackle the aforementioned limitations of the text-format reports and the traditional inspection data repositories, by utilizing an ontology-based approach for developing a process equipment inspection knowledge base. The ontology-based approach provides relations among data and enables semantic search capability, which leads to more effective and efficient knowledge retrieval, distribution, and management [12]. Additionally, the semantic structure provided by an ontology eases the multidisciplinary communication and information exchange between both humans and computers. It is a valuable tool to enable unambiguous communication and the synchronization of perspectives among collaborating teams and the interoperability and integration of tools and applications [13]. Moreover, through its structural knowledge representation, ontology diminishes the barrier to the reuse of the inspection knowledge domain [14-16].

In this study, the Inspection Knowledge Base Ontology (IKBO) is constructed to represent concepts, relations, attributes, and instances relevant to the inspection knowledge domain. To demonstrate the application of the IKBO, in facilitating knowledge and data retrieval from a collection of inspection results, a case study is provided.

BACKGROUND

Overview of Ontology

In philosophy, ontology is the study of the nature of being, existence, or reality. The study is based on a set of fundamental propositions or views of the world (i.e., epistemology) [17] and covers the identification and description of entities in terms of their existence [18]. However, in recent years, research in the domain of artificial intelligence, computer science, and information systems has used the term 'ontology' to define a formal model of knowledge that creates a shared representation and an agreement of meaning of concepts within a particular domain that both computers and humans can understand [7, 11]. Ontology enables explicit assumptions to be made regarding the domain knowledge [19]. The explicit nature of ontology makes it easier for users to find, understand, and change assumptions related to the domain knowledge [19].

Most ontologies have four key components: class, relation, attribute, and instance [20, 21]. A class is a concept that is described in the domain ontology. A relation connects two classes by providing them with an association. An attribute characterizes classes by providing them with features, properties, or parameters. An instance is a member of a particular class that may include concrete objects and have specific knowledge [21].

Ontology is normally encoded in the Web Ontology Language (OWL). OWL is one of the most popular ontology languages [7] and is recommended by the World Wide Web Consortium (W3C) for the semantic web [22]. OWL was initially developed to improve information transmission on the Internet [7]. However, its use has been extended to provide structured model of knowledge representation through formal semantics and to support interoperability in distributed computer systems [11, 23].

OWL was developed on top of the Resource Description Framework (RDF). Due to its ability to represent information in a consistent manner, RDF enables information from various sources to be gathered and treated as if they came from a single source [24]. An RDF data model is structured in the form of *subject-predicate-object*, known as triples [25]. The subject designates the resource and the predicate expresses the property of the resource [26]. The object relation with the subject is also expressed by the predicate. RDF has a schema language called RDFS to provide a sense of meaning to the data [24]. RDF is also supported by a semantic query language, known as SPARQL Protocol and RDF Query Language (SPARQL), which enables the retrieval and manipulation of data stored in the RDF format [27]. SPARQL appeals to various users because it enables convenient and easy data querying [27].

Inspection Management Process

Inspection is a critical part of onshore and offshore oil and gas production and processing operations because of its influence in upholding the safety, reliability, and availability of the equipment. Inspection does not directly mitigate degradations, but the information gained through inspection can generate insights related to the current condition of equipment, the type of degradation mechanism, and the severity and location of the degradation [4]. This information allows operators to assign necessary mitigation actions (e.g., maintenance, modification, and/or replacement), such that degradations can be controlled, and equipment failure can be prevented [28, 29].

Nevertheless, thorough inspection for all equipment in a production and processing facility is not practical, due to the large amount of equipment in the facility and the high cost of performing inspection [30]. A cost-effective and -efficient inspection plan is needed to maximize the availability of the equipment, with minimum cost and without sacrificing compliance to the regulatory and corporate requirements [31]. Prescriptive/time-based inspection is used as the industry standard for developing the inspection plans for individual items of equipment [32]. In recent years, prescriptive inspection planning has been replaced by RBI planning, which emphasizes inspecting equipment that poses the greatest RoF to the system [33]. Generally, RBI creates a more effective and efficient inspection plan than conventional prescriptive inspection planning, by allowing operators to focus their inspection resources on higher-risk equipment. The ability to prioritize inspection activities based on RoF enables the optimization of inspection plans, by hindering the over-inspection of lower-risk equipment and the under-inspection of higher-risk equipment [34].

A generic RBI assessment process is shown in Fig. 1. RBI starts with data and information collection. Historical inspection and maintenance records are among the essential data and information that are indispensable in the RBI assessment process [4]. Subsequently, the risk assessment process is performed to assign RoF to the individual items of equipment. In the RBI methodology, RoF is the product of probability of failure (PoF) and consequence of failure (CoF).

PoF is assessed by factors that influence equipment failure rate (e.g., operating and design conditions, inspection and failure history, degradation rate, etc.), while CoF is evaluated based on the variables that impact the failure events (e.g., equipment containment type, operating conditions, containment volume, etc.) [35].

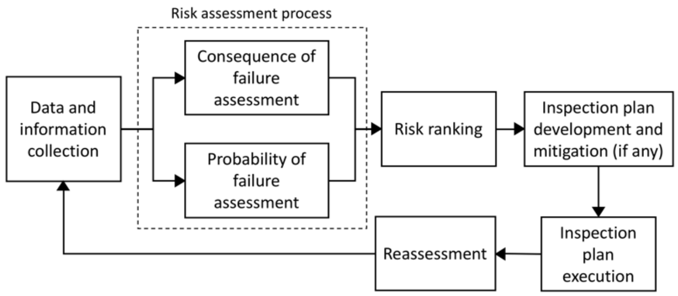


Fig. 1 RBI assessment process (adapted from [4])

The individual equipment is ranked, based on the results of the risk-assessment process. Equipment with higher RoF will have a more rigorous inspection plan (i.e., more frequent inspection with extensive inspection techniques). Risk-mitigation activities are required to be implemented if inspection activities do not effectively reduce the equipment RoF [36].

The developed inspection plan is then executed accordingly. The most recent inspection results are used to reassess and update the RBI assessment, to anticipate any changes in deterioration rate, especially in the case of damage mechanisms that are time-dependent [4]. Thus, we can argue that inspection history is a critical element of the inspection management process, which must be managed properly, in order to allow more effective and efficient risk assessment, knowledge reuse and retrieval, and collaboration/communication among stakeholders in inspection activities.

RESEARCH METHODOLOGY

In this paper, the development process of the IKBO is adapted from Fernández-López, Gómez-Pérez and Juristo [37]. The overall process of the ontology development consists of four stages (see Fig. 2): knowledge specification, knowledge acquisition, knowledge conceptualization, and knowledge formalization. Each of these stages is discussed in the following sub-sections.

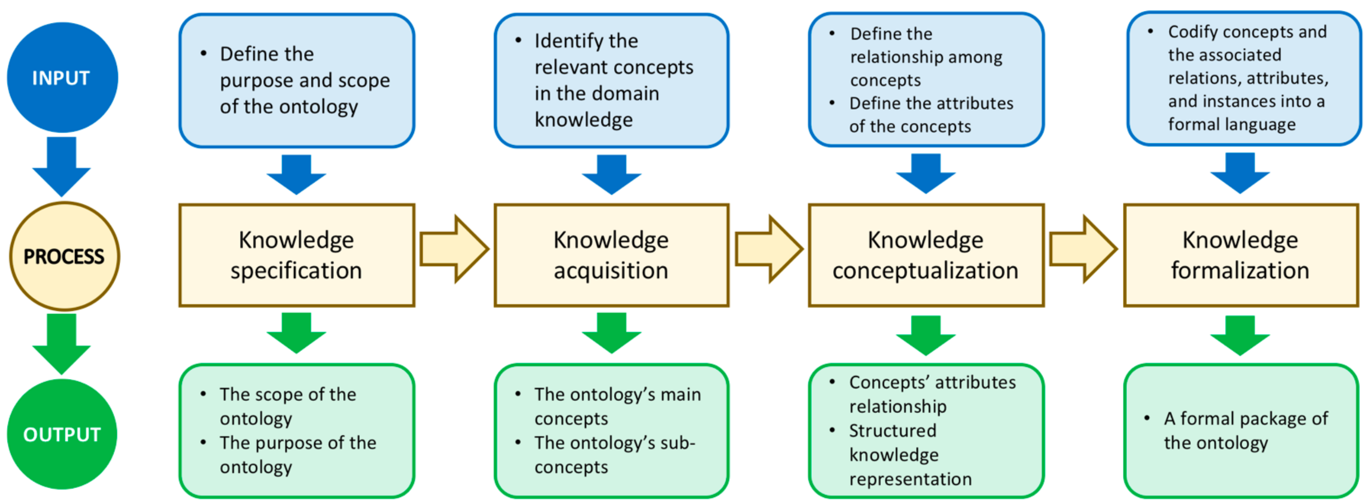


Fig. 2 The development process of the IKBO adapted from [37]

Knowledge Specification

The main goal of the specification phase is to describe the purpose and scope of the ontology being developed [37]. As mentioned in the introduction, the purpose of the IKBO is to construct an equipment inspection knowledge base, in order to facilitate more effective and efficient knowledge retrieval, distribution, and management, and to improve communication and collaboration among stakeholders in inspection-related activities.

There are various types of equipment in the oil and gas production and processing systems (e.g., pressure vessels, tanks, pumps and compressors, pressure relief devices, etc.), and they require different inspection specifications. The scope of IKBO is the inspection knowledge base for the process equipment categorized as pressure vessels, as defined by *ASME Boiler and Pressure Vessel Code* [38].

Knowledge Acquisition

Knowledge acquisition involves identifying and elucidating relevant concepts, attributes, relations, and instances in relation to the inspection knowledge domain [37]. A concept can be defined as a collection of things that possess at least one shared characteristic [8]. In the case of inspection-related activities, a concept is any entity that is required to be recognized during the management and performance of inspection.

Inspection activities in the oil and gas industries follow specific industrial standards, engineering best practices, and company specifications. API 510 [39], an industrial code that covers the in-service inspection, rating, repair, and alteration of hydrocarbon and chemical process pressure vessels, is selected as the main source to identify the relevant terms in the inspection knowledge domain. API 580 [4] and API 581 [35], the industrial standards for RBI assessment, are used to complement API 510. Although industrial standards and codes are available, each oil and gas operator normally has its own guidelines and specifications for performing inspection. Therefore, a collection of pressure vessel inspection reports from an oil and gas operator is used to ensure the completeness of knowledge in the IKBO.

The process industries have ISO 15926, which provides a common data model and reference data library to consolidate the meaning of information and to facilitate integration, sharing, and exchange of data in process plant activities throughout the life cycle [40]. ISO 15926 specifies concepts and relations that can be used to describe all things related to plant operations, plant equipment, and process behavior [7]. To ensure integration with ISO 15926, all the concepts, relations, attributes, and instances acquired from the aforementioned industrial standards and company documentations are cross-checked against ISO 15926.

Knowledge Conceptualization

The knowledge-acquisition step generates unorganized knowledge in the form of terms (e.g., instances, concepts, relations, and attributes) [41]. The purpose of the conceptualization phase is to arrange these terms into a structured model that describes the corresponding domain [37]. The terms identified in the knowledge-acquisition step are analyzed in relation to their meanings and usability in the inspection knowledge domain. API 510, API 580, API 581, and a collection of pressure vessel inspection reports from an oil and gas operator are used to determine the attributes and relations between the identified concepts.

Concept classification trees are developed to understand the hierarchical relationship between individual terms [41]. Subsequently, the relationship between concept classification trees is made by utilizing a binary relations diagram [41]. Moreover, the properties, features, and/or parameters of each concept are defined using the attributes from the available terms. The overall output of this phase is a well-structured knowledge representation, containing all the concepts and their associated relations, attributes, axioms, and instances.

Knowledge Formalization

All the concepts and their associated relations, attributes, and instances from the knowledge-conceptualization step are codified into a formal language. OWL, the standard language for ontology construction set by W3C (World Wide Web Consortium) [42], is used to formalize the knowledge. Knowledge formalization is supported by Protégé 5.2.0, which is open-source software for building intelligent systems based on OWL language [43].

INSPECTION KNOWLEDGE BASE ONTOLOGY: TAXONOMICAL STRUCTURE AND IMPLEMENTATION

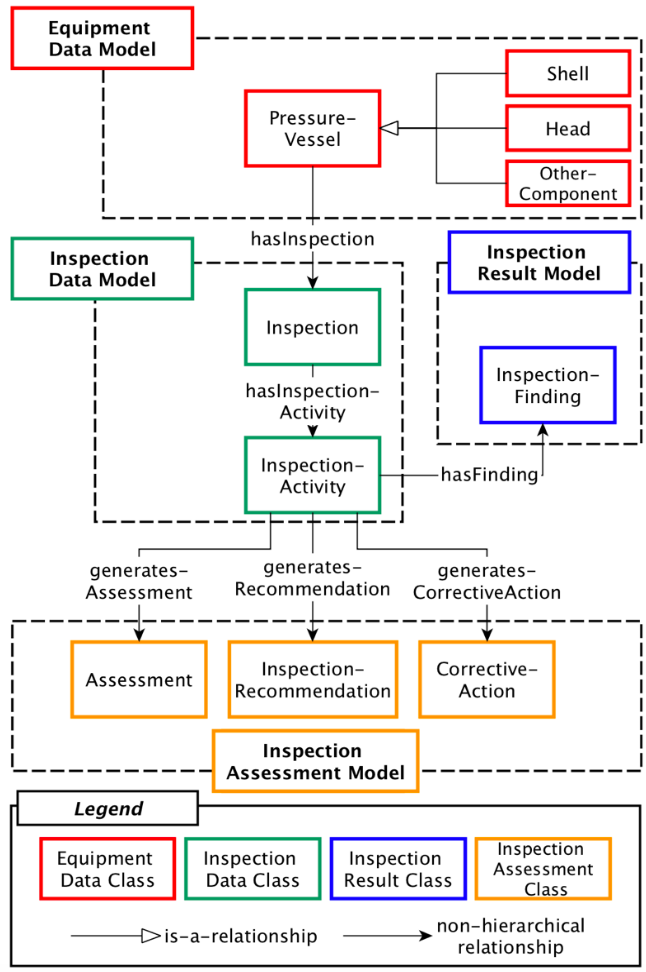


Fig. 3 The structure of the IKBO

As shown in Fig. 3, the IKBO consists of four main domain ontology models: *Equipment Data Model*, *Inspection Data Model*, *Inspection Result Model*, and *Inspection Assessment Model*.

The *Equipment Data Model* contains basic information about the equipment. Only equipment categorized as a pressure vessel is considered in this study. The main class of this model is the *PressureVessel* class, which is divided into three subclasses: *Shell*, *Head*, and *OtherComponent*. The *Shell* and *Head* class include pressure-containing components and their associated protections that are attached to the main body of the vessel. Among components that are included in *Shell* and *Head* class are nozzles, circumferential/longitudinal welds, insulation/cladding, coating, etc. Meanwhile, the *OtherComponent* class comprises auxiliary components and instrumentations that are still part of the vessel. Earthing strap, ladder, stairway, and pipe support are some examples of components that belong to *OtherComponent* class.

The *Inspection Data Model* includes data and information regarding the inspection of the pressure vessel. It comprises of two main classes: *Inspection* and *InspectionActivity*. The *Inspection* class comprises of one or more *InspectionActivity* classes, and they are connected through the *hasInspectionActivity* property. It is deemed necessary to have both *Inspection* and *InspectionActivity* classes because an inspection normally consists of smaller inspection activities, i.e., the *Inspection* class is the parent of the *InspectionActivity* class.

The *Inspection* and *InspectionActivity* classes can be further described, as shown in Fig. 4. The *InspectionActivity* class (Fig. 4b) comprises relations and attributes that characterize an inspection activity. The *InspectionType* class explains the category of inspection that is being performed. API 510 specifies six types of inspection that can be performed on a pressure vessel: internal inspection, on-stream inspection, external inspection, thickness inspection, corrosion under insulation (CUI) inspection, and operator surveillance. The *VesselSection* class describes the part of the vessel where the inspection is performed. Terms such as northern/southern/eastern/western and top/middle/bottom are normally used to indicate the vessel section. The *InspectionObject* class explains the component of the vessel being inspected. This can be the shell, head, transition cone, nozzle, manway, or other components of the vessel. The *InspectionTechnique* class specifies the type of technique that is used to conduct the inspection. Visual inspection, ultrasonic thickness measurement, radiographic test, and eddy current test are some examples of instances that belong to the *InspectionTechnique* class. The *InspectionActivity* class also has some attributes that provide basic information regarding the inspection, such as inspection date, the name of the inspector, and the coverage area of the inspection.

Meanwhile, the *Inspection* class (Fig. 4a) relates to the *InspectionEffectiveness* class through the *hasInspectionEffectiveness* property. The *InspectionEffectiveness* class signifies the capability of the inspection in detecting and locating degradation, as well as in determining the extent of the degradation [35]. The effectiveness of an inspection is estimated by aggregating several inspection activities that are performed in a time proximity and is a function of the type of inspection techniques being used and the total inspection coverage area [35].

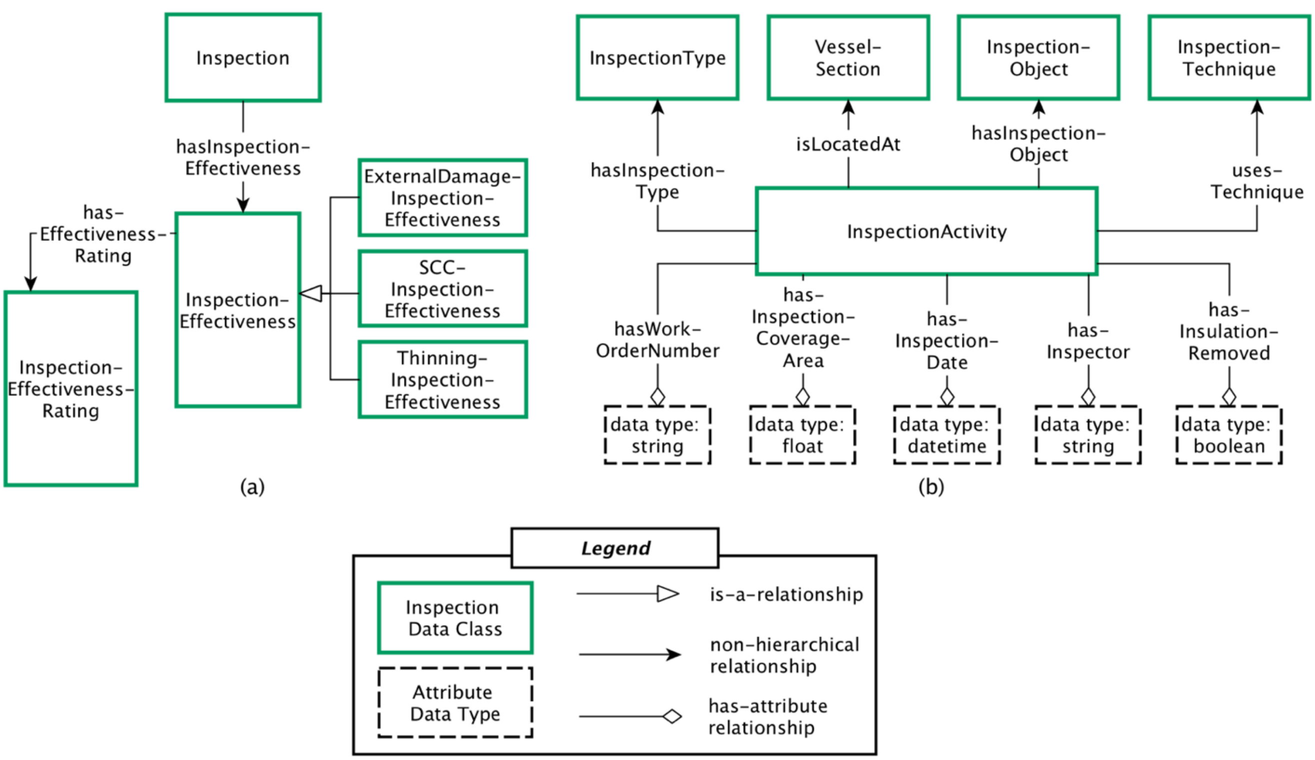


Fig. 4 (a) *Inspection* and (b) *InspectionActivity* class in the Inspection Data Model of the IKBO

The *Inspection Result Model* consists of data and information about the findings made during the inspection. The *InspectionFinding* class (Fig. 5) is the main class of this model and has relations and attributes that assert the detailed descriptions regarding an observation. It has relations with the *DefectType* class, which designates the type of defect (e.g., corrosion, crack, fracture, etc.) the inspector has found during the inspection. A detailed explanation about the finding and/or defect is given by the *hasFindingDescription* attribute. The Uniform Resource Locator (URL) of the images generated from the inspection activity can be inserted through the *hasImage* attribute.

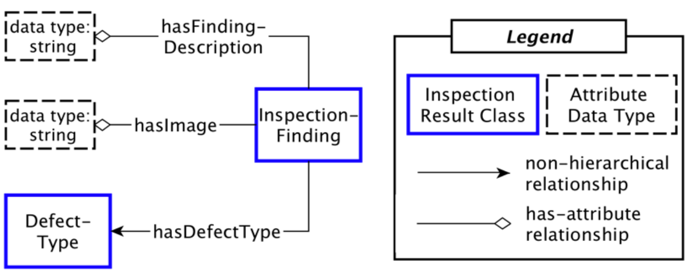


Fig. 5 *InspectionFinding* class in the Inspection Result Model of the IKBO

The *Inspection Assessment Model* contains the knowledge about the evaluation and assessment of the inspection result. It comprises three main classes: *Assessment*, *InspectionRecommendation*, and *CorrectiveAction*. The *Assessment* class gives information about the evaluation concerning the general condition of the inspected component, by taking account of all the inspection findings. Terms such as *acceptable* or *unacceptable* can be the instances of this class.

Meanwhile, the *InspectionRecommendation* (Fig. 6a) and the *CorrectiveAction* (Fig. 6b) classes provide information about the recommended and the corrective actions that are deemed necessary after assessing the inspection results. The *InspectionRecommendation* class has the *hasRecommendationDescription* attribute to describe the specified recommendation action in a detailed manner. Each inspection recommendation is ranked through the *RecommendationRank* class, in order to select the inspection recommendation that should be prioritized. Similarly, the *CorrectiveAction* class has the *hasCorrectiveActionDescription* attribute to describe the specified corrective action in a detailed way. The *CorrectiveAction* class is related to the *CorrectiveActionRank* class, to enable prioritization of the corrective action implementation.

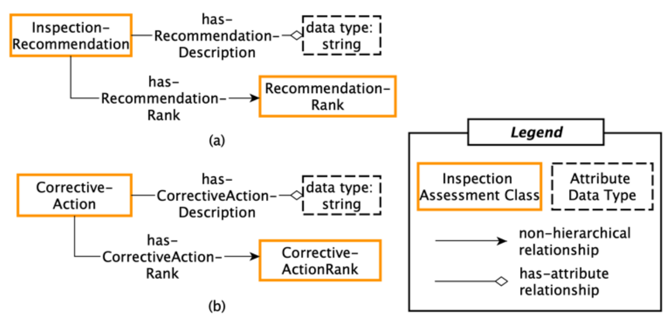
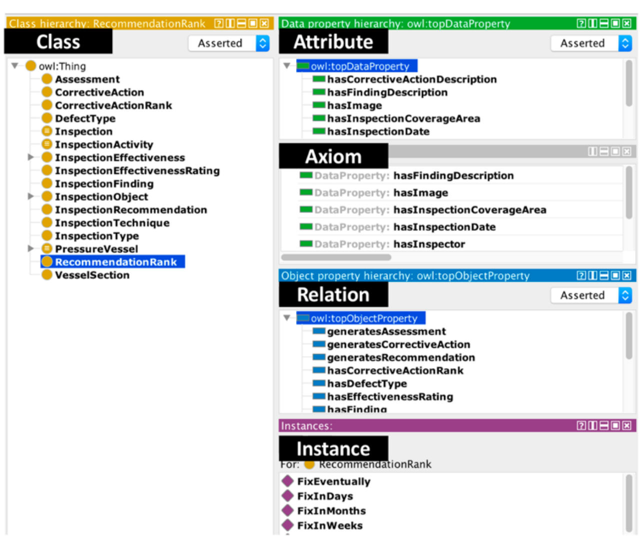


Fig. 6 (a) *InspectionRecommendation* and (b) *Corrective Action* class in the Inspection Assessment Model of the IKBO




```
<owl:Class rdf:about="http://www.semanticweb.org/andikarachman/
ontologies/2018/7/inspection-knowledge-base-ontology#Inspection">
    <owl:equivalentClass>
        <owl:Class>
            <owl:intersectionOf rdf:parseType="Collection">
                <owl:Restriction>
                    <owl:onProperty rdf:resource="
                    http://www.semanticweb.org/andikarachman/ontologies/
                    2018/7/inspection-knowledge-base-ontology#hasInspect
                    ionEffectiveness"/>
                    <owl:allValuesFrom rdf:resource="
                    http://www.semanticweb.org/andikarachman/ontologies/
                    2018/7/inspection-knowledge-base-ontology#Inspection
                    Effectiveness"/>
                </owl:Restriction>
                <owl:Restriction>
                    <owl:onProperty rdf:resource="
                    http://www.semanticweb.org/andikarachman/ontologies/
                    2018/7/inspection-knowledge-base-ontology#hasInspect
                    ionActivity"/>
                    <owl:minQualifiedCardinality rdf:datatype="
                    http://www.w3.org/2001/XMLSchema#nonNegativeInteger"
                    >1</owl:minQualifiedCardinality>
                    <owl:onClass rdf:resource="
                    http://www.semanticweb.org/andikarachman/ontologies/
                    2018/7/inspection-knowledge-base-ontology#Inspection
                    Activity"/>
                </owl:Restriction>
            </owl:intersectionOf>
        </owl:Class>
    </owl:equivalentClass>
</owl:Class>
```

(a) (b)

Fig. 7 (a) An excerpt of the IKBO in Protégé and (b) A snippet of the OWL code for defining inspection class

All the concepts, relations, attributes, and instances contained in the IKBO are captured and coded into the OWL language by using Protégé software for knowledge formalization. Protégé acts as the ontology editor, enabling modifications and inspections of the ontology's concepts, relationships, attributes, axioms, and instances. Fig. 7a exhibits an excerpt of the IKBO in Protégé, while Fig. 7b shows a cross-section of the OWL code for defining *Inspection* class in the IKBO.

THE APPLICATION OF INSPECTION KNOWLEDGE BASE ONTOLOGY IN THE RETRIEVAL OF INSPECTION DATA AND INFORMATION

In this section, an example of the IKBO is presented to demonstrate its applicability. Suppose that we have past inspection activity for a pressure vessel, with details as shown in Table 1. The inspection covers all components of the pressure vessel, including the vessel main body (e.g., shell, head, circumferential/longitudinal welds, nozzle, etc.) and auxiliary components (e.g., fireproofing, earthing strap, firefighting equipment, etc.). A report containing findings of the inspection activity is identified. An excerpt of the inspection findings is shown in Fig. 8.

Suppose that our interest lies in retrieving information about the inspection findings exclusively on the circumferential and longitudinal welds of the aforementioned pressure vessel. Querying that information in a conventional inspection report and data repository would not be possible because of their lack of capability to use relationships among concepts. On the contrary, the IKBO provides a semantic structure for concepts in the inspection domain, which enables semantic search capability from relationships between concepts. This leads to the improvement of the inspection database in searching and finding information [12].

Data and information related to the inspection of the pressure vessel can be structured into the IKBO. Based on those data and information, the instances related to the inspection of the pressure vessel can be created. An example of instance generation, based on data presented in Fig. 8 and Table 1, is shown in Fig. 9.

Table 1 Basic information of the inspection activity

Inspection Details		
Pressure Vessel ID	:	V-2264A
Inspection Type	:	External Inspection
Inspection Technique	:	General Visual Inspection
Inspector	:	E. Hasan
Work Order Number	:	13707
Inspection Date	:	2 August 2012
Inspection Coverage Area	:	100% of External Surface
Insulation Removed?	:	Not Insulated

…Vessel data nameplate and vessel equipment identification tag number label were attached vessel. The western half of vessel shell and its dome-end were fully insulated or coated in fireproofing material while the remaining eastern half of the vessel shell and its dome-end were coated in protective paint. Vessel appeared to be on-line at the time of inspection.

Inspection of the western half of vessel was limited to the fireproofing material used on that side of the vessel. Fireproofing material was intact and in good condition apart from old mechanical damaged scratch marks which had been repaired visible near on the top-side of vessel. Other associated components on the vessel western-side were in satisfactory condition.

Vessel eastern half shell, dome end, nozzles, manway, attachment welds and associated components were in satisfactory condition. No process leak traces or mechanical damage or corrosion activity was sighted on the vessel. Circumferential and longitudinal welds of vessel where easily seen appeared in good condition. Associated protective coating or paint of eastern half of the vessel was also in sound condition.

Vessel fire deluge system that was installed over the entire vessel was well in tack and in sound condition. Associated components of the system such as pipe spools, pipe flanges, bolts & nuts were sighted in good and secure condition with no signs of leaking gasket detected. Fire deluge system guy wires were also in good and secure condition…

Fig. 8 An excerpt from the inspection finding part of the pressure vessel V-2264A inspection report

As shown in Fig. 9, the IKBO develops a structure that categorizes inspection data and information based on several classes, such as *InspectionType*, *InspectionTechnique*, *InspectionObject*, and *VesselSection*. This creates convenience in querying specific information about an inspection activity based on those classes and their relationships and attributes. Some classes, such as *Inspection*, *InspectionActivity*, and *InspectionFinding*, do not contain actual information or classification related to the inspection, but they act as mark-ups that describe any relations and attributes connected to them. These classes' role is similar to annotation in a conventional document, which improves the retrieval of data and information and enables the document to be processable by humans and computers [7].

Based on the IKBO, SPARQL can be used to perform an ontology-based search, by using a query similar to Structured Query Language (SQL). To retrieve the information about the findings of inspection (performed on 2 August 2012) on the circumferential and longitudinal welds of pressure vessel V-2264A, a SPARQL query can be formulated on the ontology as follows:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX ary:
<http://www.semanticweb.org/.../inspection-knowledge-base-ontology#>
SELECT ?FindingDescription ?DefectType
WHERE {
   ?InspectionFinding ary:hasFindingDescription ?FindingDescription .
   ?InspectionFinding ary:hasDefectType ?DefectType .
   ?InspectionActivity ary:hasFinding ?InspectionFinding .
   ?InspectionActivity ary:hasInspectionObject ary:CircumferentialLongitudinalWeld .
   ?InspectionActivity ary:hasInspectionDate "2012-08-02T00:00:00"^^xsd:dateTime .
 }
```

where the SELECT clause describes the part(s) of RDF data that need(s) to be retrieved and the WHERE clause defines the criteria of data used by a query [27]. The ontology and its elements are identified using Internationalized Resource Identifiers (IRIs) [44]. For instance, the IKBO is identified by the IRI, http://www.semanticweb.org/andikarachman/ontologies/2018/7/inspection-knowledge-base-ontology. The PREFIX clause allows IRIs to be abbreviated by prefixes. From the query, we can see that the IRI of the IKBO has been abbreviated with the prefix, “ary”. IRIs with other prefixes (e.g., rdf, owl, rdfs, and xsd) contain the reserved vocabulary of OWL. Meanwhile, the items that are preceded by a question mark are those that need to be found and matched in the ontology.

The application of this querying method is particularly important when the users intend to retrieve several inspection records at the same time. For instance, in the case of RBI assessment, a collection of inspection reports from the last five years is generally required as the basis to determine the type of damage mechanism and the degradation rate affecting the pressure vessel. The IKBO can be highly useful to ease the retrieval, distribution, and management of these inspection reports.

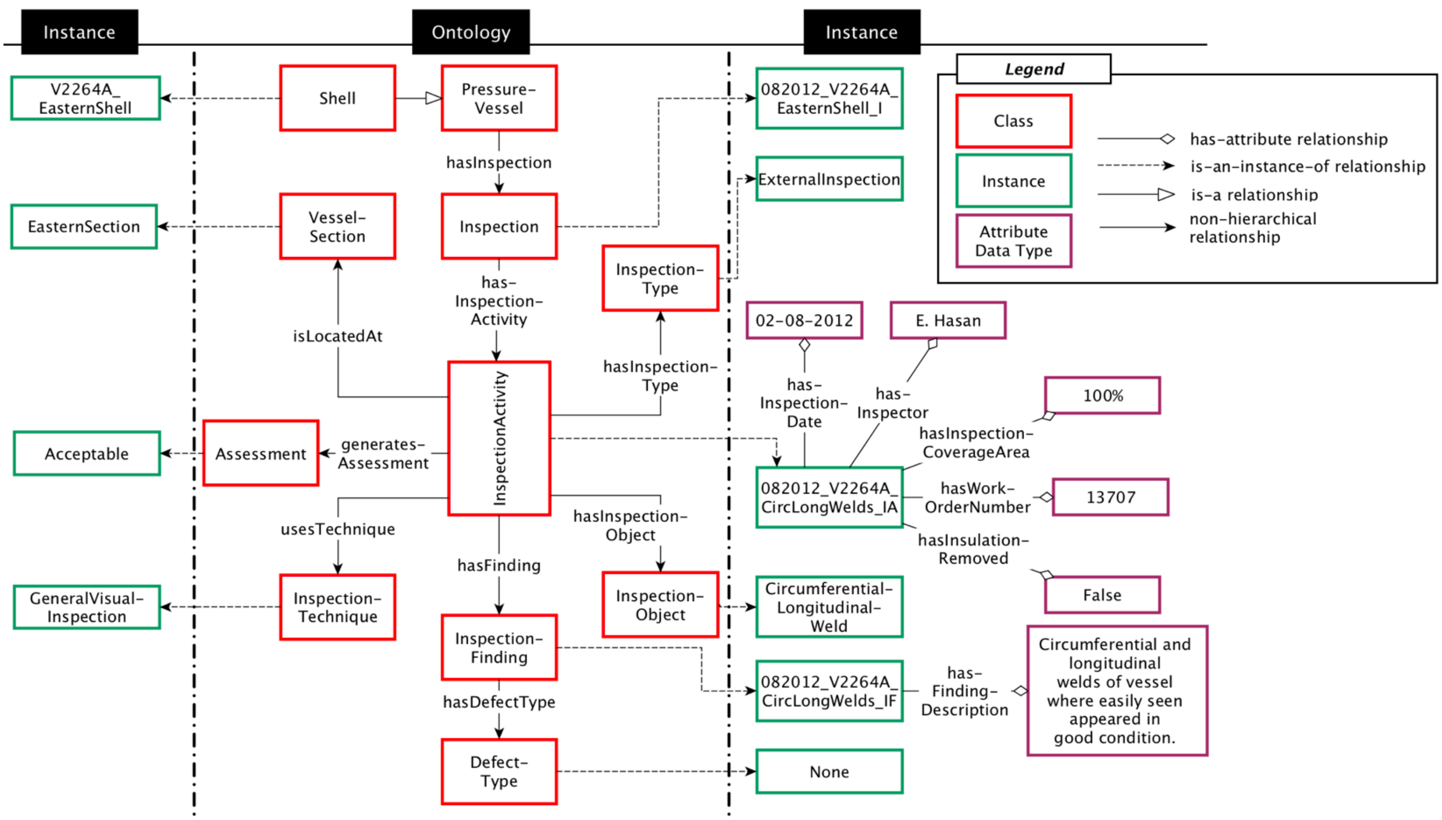


Fig. 9 IKBO instances for the inspection of pressure vessel V-2264A (circumferential and longitudinal welds only)

CONCLUSION

This study discusses the application of an ontology-based approach to facilitate the development of an inspection knowledge base for process equipment. This study emphasizes how an ontology can improve communication and information exchange, between both humans and computers, and facilitate the reuse of the inspection knowledge domain.

The IKBO is constructed to represent concepts, relations, attributes, and instances relevant to the inspection knowledge domain. It eliminates the drawbacks of the text-format report and traditional data repository, which are static and lack formal knowledge representation. The IKBO provides a semantic structure for concepts in the inspection knowledge domain, which enables semantic search capability and leads to more effective and efficient knowledge retrieval, distribution, and management.

Another advantage of using the ontology-based approach is its ability to be the foundation for creating unambiguous communication and information sharing, as well as synchronizing perspectives among collaborating teams. This is particularly important, considering the multi-disciplinary nature of inspection-related activities. The formal knowledge representation provided by the IKBO can create a shared and common understanding of the inspection knowledge domain that facilitates ease of communication among stakeholders.

The development of ontology in this study is limited to the process equipment categorized as a pressure vessel. There are various types of equipment in oil and gas production and processing systems (e.g., tanks, pumps and compressors, pressure relief devices, etc.) that require different ontological structures. Future study should focus on the construction of inspection and maintenance knowledge base ontology for the aforementioned equipment.

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