



Impact of Ontology in Aviation Incident and Accident Knowledge Repository

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ABSTRACT

The aviation industry is one of the most critical industries where access to quick and detailed information is very crucial for saving human lives and preserving the life span of the expensive fleet of aircraft. One of the most important problems with accident and incident reports in the aviation industry is that they are usually manually based or accessed and, in most cases, the outcome is usually based on hardcopy reports or standalone softcopies and are fragmented on the World Wide Web, and this makes logical inference cumbersome. However, documenting accidents and incidents in a database system is a good way to make these reports easily and logically accessible as knowledge for making informed decisions on any potential aspects to take note of, in order to enhance aircraft safety. This paper presents an Ontology-based knowledge representation language to facilitate explicit interpretation of domain resources and data. Coupled with its interoperability function, ontology presents the best choice for modelling such database domain. Ontology was developed in Protégé using the template of the accident and incident manuals and was tested by querying it for accident and incident information which returned results based on the search criteria and the information in its database. Access to logical information in a database system for accidents and incidents in the aviation industry would facilitate the understanding of the structure of the data that can be used by humans as a source of knowledge of the things in the domain of a function for software for further computational task or analysis would go a long way in mitigating some avoidable incidences.

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INTRODUCTION

Aircraft accidents and incidents in the aviation industry (either military or commercial) cannot be totally averted; however, some are mostly as a result of improper information of previous incidences which if properly researched and grouped logically, can enhance the knowledge of players in the industry in mitigating such future occurrences. From an aircraft accident that occurred in Nigeria - a military aircraft Beechcraft King Air B350i that crashed in May, 2021 due to reported engine failure, to the aircraft incident of a commercial aircraft due to tyre burst in July 2021, and to that of the Siberian light aviation domestic flight reported in September,

2021 to have been crashed off the runway due to a heavy fog while landing with four fatalities, signals the fact that most of these accidents and incidents happened when it is least expected. This is a global challenge owing to the complexity of aircraft design; as such it is a common occurrence that aircraft components could fail (Zhao *et al.*, 2018). However, it has been adjudged that most of the accident and incidents are as a result of human error and natural disaster that makes the aircraft system deviates from the predicted working and environmental conditions.

Usually, when an aircraft is involved in an accident or an incident, depending on the country investigating it, a team of experts are

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assembled to investigate the accident or incident and report the findings on the cause of accident or incident. In most cases, the reports are submitted in hard copies (Hughes *et al.*, 2019), and when made available online for the public use, it is usually fragmented (Zhao *et al.*, 2018) – as not all maybe arranged in a logical way for easier use and application of the stakeholder and populace, hence the need to have a knowledge-based system for logical collation and reporting accidents and incidents occurrences in the industry. The aviation industry is one of the most critical industries where access to quick and detailed information is highly crucial, therefore, quick access to logical accidents and incidents information in a Database Management System in the aviation industry would facilitate the understanding of the structure of the data that can be used by humans as a source of knowledge for easy consumption or a function for a software for further computational task or analysis.

There have been numerous cases of accidents and incidents in the aviation industry, Ontology serves as a tool that gives data meaning for an informed reasoning during a decision-making process (Su *et al.*, 2016). It describes concepts and the relationships that can exist among the concepts and things in the domain of interest. It aids reasoning and can accommodate data from different sources. Ontology is made up of classes, properties, instances and the logical relationships that connect them all. Ontology can be represented in different representation language, the accident and incident ontology was implemented in web ontology language (OWL). The OWL is used out of all the knowledge representation languages due to its expressivity (Shobowale, 2018) as it combines the resource description framework (RDF) and the extensible mark-up language (XML) flavours (Su *et al.*, 2016). Ontology has been used in different context such as in regulating aviation supply chain management (Milambo & Phiri, 2019), in regulating cyber security (Talib *et al.*, 2018; Aliu *et al.* 2021), in software as a cloud services on the cloud (Otuka *et al.*, 2017; Chinedu *et al.*, 2021) to name a few.

LITERATURE REVIEW

Knowledge base systems stores data as information to support decision making process. Ontologies are multipurpose; it can be

used for solving issues in data modelling, querying, knowledge base and decision support (Shobowale, 2018). Industries that have profited from the use of ontology includes: Healthcare (Health information regulation, sharing Health information, making Health recommendations accessible), Education, Supply Chain, Governance and Construction etc. Ontologies have been handy for data interoperability, flexible data exchange, distributed data management, and the development of reusable tools (Kondylakis *et al.*, 2021). The work by (Asim *et al.*, 2018) reported that owing to ontology capability to give explicit semantics and its interoperability and stressing the importance of reuse of domain knowledge, they concluded that Ontology makes domain knowledge more explicit and that with Ontology, it's easier to analyse domain knowledge. For aviation, data analysis of aviation is challenging, especially in the management of air traffic flow management (Aghdam *et al.*, 2021). They further reiterated that proper management and analysis of diverse data can minimize human error and consequently aircraft accidents and incidents.

Ontology has seen some matured usage in many industries (such as the health care, transport, oil and gas to mention a few), in the transport industry for example, (Hughes *et al.*, 2019) used 5065 free-text multi-lingual (German, French and Italian) safety incident reports from the Swiss Federal Office of Railway Transport was used to develop safety ontology. Different categories of injuries to passengers made up the classes. The ontology was queried using a graph database when information on incidents is required. Human evaluators were used for the validation. The aviation industry has seen some emerging usage in the aspect of using it as a database system. In recording aviation occurrences, (Kremen *et al.*, 2017), developed a database for recording data on accident and incident records that occurred solely in the European region.

The work by (Saeeda, 2017), designed information extraction and semantic annotations iterative ontology for safety reports of aviation while (Ledvinka *et al.*, 2019), proposed ontology as a technology for data management in safety. They designed an ontology information system for integrating aviation safety data. Also, knowledge sharing



in aircraft maintenance and retrieval of database aircraft fault ontology was provided by (Yang 2011), using similarity matching algorithm based on nearest neighbour to retrieve results of the query.

The work by (Aghdam *et al.*, 2021) developed internet protocol suite-based aviation networks ontology using methontology methodology for the ontology development. Their scope was the engineering of flight messages ontology implemented in Protégé software. They concluded that the semantic web has solved the issue of finding meaning to data with ontology also known as knowledge graphs for connecting data and finding relationships through inference to make informed decisions. Also, (Ledvinka *et al.*, 2018), developed aviation safety data collection and processing ontology information system for safety data while (Zhao *et al.*, 2018), designed a construction risk-based aviation ontology and tested using the American Aviation safety reporting system. More so, an ontology for knowledge management procedures in aviation departures

was designed by (Su *et al.*, 2016). According to (Haendel *et al.*, 2018) ontologies defers from terminologies, ontologies define relationships between concepts making it easy for computational logical reasoning which then makes the drawing of logical conclusions from related assertions easy. Ontology comprises of a set of concepts (terms of the domain represented in classes and subclasses) together with their synonyms which is depicted in their annotations, individuals or instances that are members of the classes or subclasses, data and object properties that links the instances together as well as description-logic definitions that specify the formal relationships between the concepts. Terminologies are simply meaning of terms in the domain. Description logic in ontology makes the ontology logically consistent, this paper is concerned with the documentation of accident and incident data records for easy and prompt retrieval of information. Ontology can be developed using different editors, Table 1 highlights the differences in various editors.

Table 1: Comparison of Ontology Editors (Shobowale, 2018)

Ontology Editors	Source	Reasoner/ Query	Representation Language	Extensibility	Status
Protégé	Open (Stanford University and University of Manchester)	Pallet, Fact++, Hermit / DL Query, SPARQL	RDF, OWL, OWL2, Rules (SWRL)	Extensible with many plug-ins/ plug and play for rapid prototype and application development	Most well-known (large user and developer base) / java based
Onto Studio	Commercial (ontoprise GmbH)	F-logic	RDF, Rules	Not extensible	Fairly known
SWOOP	Open (MIT)	Pallet	OWL	Not extensible	Fairly known
Neon toolkit	Commercial (Consortium of European research)	KAON2	RDF, OWL2	Extensible	Fairly known
TopBraid Composer	Commercial (TopQuadrant)	Pallet / SPARQL	RDF, OWL, Rules (Jena)	Not extensible	Not too well known

METHODOLOGY

The incident and accident ontology model was developed in protégé-OWL using protégé 5.5.0 using the methodology in [Shobowale, 2018]. The steps below depict the process of ontology development:

Step 1: Determine the Purpose and Scope of the Ontology

Determining the purpose and scope the ontology will serve is the first task in creating ontology. In this paper, the purpose of the ontology is to create a knowledge-based system to facilitate easy retrieval and updating

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of aircraft incident and accident data that can perform efficient and easy to use knowledge base in the aviation industry. The scope is limited to the occurrence classification section of the accident and incident manual. Based on the identified purpose and scope that the ontology is intended to serve, this is followed by the requirement analysis that will lead to the choice of the semantic representation that will best suit the application. The knowledge representation to be used must have the capability to be easily integrated and exchanged with other knowledge sources. It must also be able to generate implicit knowledge through its deductive algorithms. Competency questions also needs to be generated to get a good grasp of the scope of the ontology, this is a list of questions that the ontology knowledge based will give answers to.

Competency question:

1. What Accident/Incident data should be stored in the ontology?
2. Can the Accident/Incident ontology be integrated with other systems for further development?

Step 2: Knowledge Acquisition

The first thing to consider is to check if there is an existing ontology in the domain of interest that can be reused. If none exist, then the ontology has to be built from scratch. The incident and accident ontology was built from scratch as there is not a publicly one available based on the authors findings. The procedures manual of aircraft accident/incident investigation appendix H, part of occurrence identification section was used to develop the ontology.

Step 3: Design and Development

This entails identifying:

1. The key concepts in the domain are the classes and its hierarchies which will form the classes and its subclasses. For occurrence identification, history of flight section, the history of flight will be a class while Airline operation (Air Transport Operations) will be a subclass. Type of operation will be a subclass of Airline operation (Air Transport Operations) while the code 0101, 0102 and 0103 will be a subclass of Airline operation (Air

Transport Operations). Instances also known as individuals are the components the ontology is built on, as in ontology classify instances. In our accident and incident ontology, instances such as 'Accident_01', 'Accident_02', and 'Incident_01' are classified by their ontology and returns results based on the other instances that make up the accident and incident ontology.

2. Properties which are either object or data properties or also called characteristics connect the instances to make them form a relationship. Object properties are used to form a relationship between two instances while data properties connect one individual with an attribute data. In the accident and incident ontology, an object property connects two instances Accident_01 and Passenger through the object property "has Type of Operation", while an instance Accident 01 connects with an attribute data (NAF203 which is of type string) through the data property 'has Registration'.

Step 4: Evaluation and Validation

The evaluation and validation serve to ensure quality assurance of the ontology. The evaluation is to measure if the purpose of the ontology has been satisfied (can knowledge can be inferred from the ontology?) and the task (the knowledge-base, information search and retrieval) the reason the ontology was built can be accomplished. The evaluation and validation can be measured on logical criteria; checking for inconsistent in the ontology using the reasoner implies modeling errors, making it impossible to be used for automatic deductions in applications. Logical consistency is the basis for a useful ontology. Ontology must be logically complete with axioms such as class disjointness, property restrictions, complex statements and expressions (Shobowale, 2018).

Knowledge Representation and Description (Modelling in OWL-DL)

Knowledge representation that is commonly used for ontology development is Web ontology language description logic (OWL-DL), a member of first-order predicate logic. The *Attributive Language with Complement* (ALC) are the basic description

logic and the classes, properties and individual (instance) are the basic building blocks. Some OWL-DL language constructs such as owl: cardinality cannot be expressed using ALC, an upgrade to a higher description logic SHOIN (D) (S for ALC and property transivity; H for property hierarchies, O for one element closed classes, I for inverse properties; N for cardinality restrictions and D for datatypes) was implemented as it contains ALC and more language constructs for more expressivity [Shobowale, 2018]. By default, there are two classes in OWL-DL which are the owl: Thing (the main class) and owl: Nothing (the empty class that stores the inferred model). A

complex class can be constructed using equation 1:

$$A, B = C \mid \top \mid \perp \mid \neg A \mid A \cap B \mid A \cup B \mid \forall R.A \mid \exists R.A \quad (1)$$

\top denotes owl: Thing; \perp denotes owl: Nothing (empty class); \neg denotes negation
 \cap denotes conjunction; \cup denotes disjunction;
 \forall denotes owl: all Values From
 \exists denotes owl: someValuesFrom; A, B denotes complex class expression
 C denotes a class name; R denotes an abstract property.

The axioms/statements of the Description logic knowledge base are TBox and ABox Statements (Figure 1).

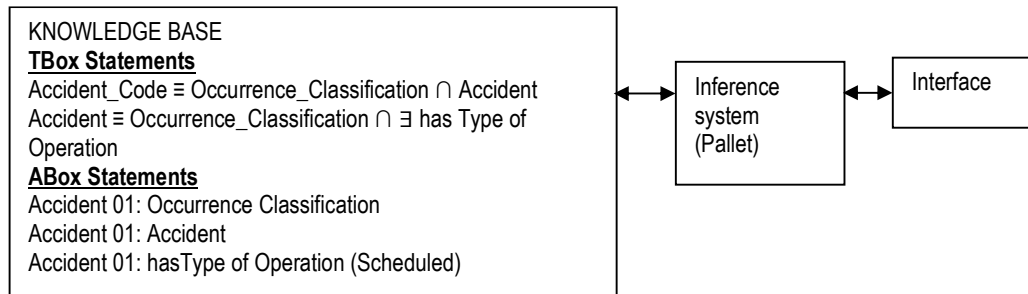


Figure 1: DL Architecture for Modelling Accident and Incident data

Domain knowledge modelled in ontology comprises of the TBox statements and the ABox statements.

TBox statements – these are the terminological knowledge used in the domain of interest. Let A and B denote two different class expressions, the expression $A \sqsubseteq B$ denotes A is a subclass of B . from the aircraft accident / incident record domain, a TBox expression can be in the form:

Accident \sqsubseteq **Occurrence_Classification;**
 denotes Accident is a subclass (type) of Occurrence_Classification.
 Accident_Code \sqsubseteq Occurrence_Classification \cap Accident
 in Figure 1 is an expression that also states that Accident_Code is a variant of Accident and Accident is a type of Occurrence_Classification.

ABox statements – these are asserted knowledge about individuals (instances) from the terminology of the TBox. The statement,

Occurrence Classification \sqsubseteq \exists **has Type of Operation** (Type of Operation); denoting all Occurrence Classification must have type of operation named type of operation which can be Scheduled, Non-Scheduled or Unknown. The asserted knowledge in Figure 1 will now be:

Accident code: has Type of Operation (Scheduled); that is Accident code a variant of Accident and it has type of operation Scheduled, meaning the aircraft that was involved in the accident was on a scheduled flight. What can be deduced from this information that the aircraft has passed the airworthiness before it was allowed to fly, it can therefore be deduced that negligence was not a factor in the accident and that other causes such as human error, deviation from the predicted conditions are the probable cause. Search for Accident that has type of operation to be on schedule will return Accident 01 and other attributes of the Accident 01 can be

viewed for further action (Figure 2). The syntax on DL Query is “Accident and has Type of

Operation value Scheduled”.

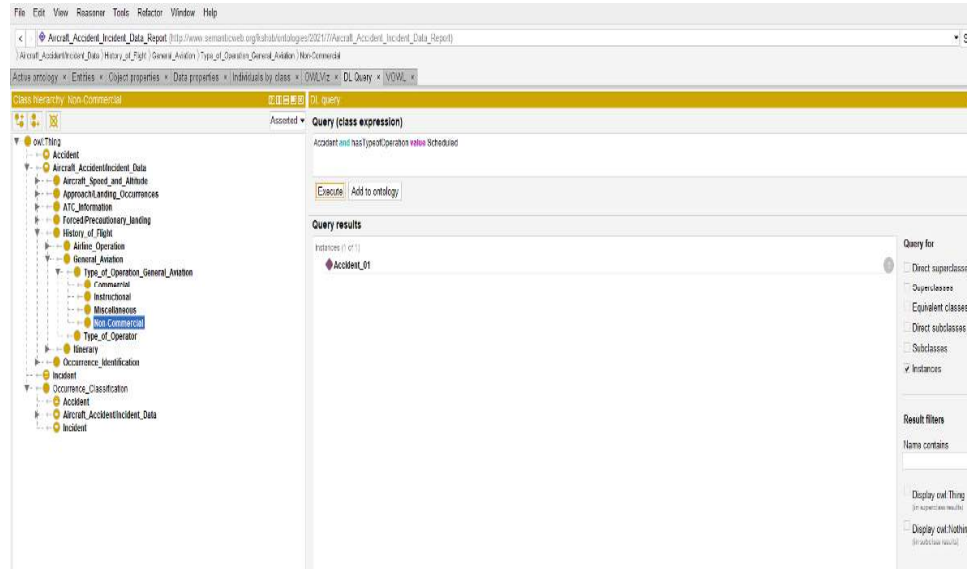


Figure 2: Description Logic Query

Classes can fall into atomic classes and properties (names of classes and properties) and complex classes and properties (constructed using description based on description logic language and then assign them names in the TBox). Accident / Incident Ontology atomic classes are Occurrence Classification, Accident, Incident and atomic property has Location Near. The TBox part is used to define the complex classes about the location where the accident or incident occurred is modeled as:

Accident \equiv Occurrence Classification \sqcap \neg Incident
 Incident \equiv Occurrence Classification \sqcap \neg Accident
 Accident \equiv Occurrence Classification \sqcap \exists has Location Near Location Near
 Incident \equiv Occurrence Classification \sqcap \geq has Location Near

The corresponding ABox of the above TBox analogy can give:
 Occurrence Classification (Accident, Incident)
 Has Location Near (State, Country)

where \equiv denotes equivalence; \sqcap denotes intersection; $\exists R.C$ or $\forall R.C$; such as in \exists has Location Near. Location Near ($\exists R.C$) denotes the sets of the individual from the set corresponding to the class C where the relation R is valid. $\geq n$ denotes value restriction on the cardinality of the corresponding set.

In conclusion, the TBox states the semantic relationships between individuals of the ABox and their properties while the ABox describes the specifics of the domain by using the classes and properties in the TBox.

RESULT AND DISCUSSION

The accident and incident data report that was used to develop the ontology knowledge base is shown in Figure 3 with the output of the ontology visualization tool, OWLviz. The class after the super class (owl:thing) is the occurrence classification class. The occurrence classification class has the accident and incident as its subclasses as both subclasses are what other entities in the ontology defines.

ACCIDENT/INCIDENT DATA REPORT

COMPILING INSTRUCTIONS

General The ADREP Manual contains all the information needed to complete this form. The report will be submitted in one of the working languages of ICAO. All codes shall be entered in capitals as should the plain language entries. It is highly desirable that all entries be typewritten. All entries are to be completed. If no other instruction is given, there may be only one entry for each identifier.

When the word "code" is found under an entry, the compiler is requested to refer to the appropriate appendix of the ADREP Manual to find the code to be entered. The plain text for the code is also then to be entered in the space provided.

Entry of figures and letters

For 0 (Zero) enter thus: 0	For A enter thus: Aa
For 1 (One) enter thus: 1	For X enter thus: AE
For 7 (Seven) enter thus: 7	For O or Ø enter thus: OE
	For U enter thus: UE

For identifiers marked with ● special coding instructions are listed in Chapter 3 of the manual.

00 — OCCURRENCE IDENTIFICATION

FILING INFORMATION

State Reporting 0001 ●	Code	Plain text
State File number 0002	Code	

OCCURRENCE CLASSIFICATION

0003	<input type="checkbox"/> Accident	<input type="checkbox"/> Incident
------	-----------------------------------	-----------------------------------

WHERE

State/area of occurrence 0004 ●	Code	Plain text
Location 0005	Local spelling using Roman letters	
Latitude 0006	Deg	Min <input type="checkbox"/> North, <input type="checkbox"/> South
Longitude 0007	Deg	Min <input type="checkbox"/> East, <input type="checkbox"/> West

WHEN

Date of occurrence 0008	Year	Month	Day
Local time of occurrence 0009 (24 h clock)	Hour	Min	

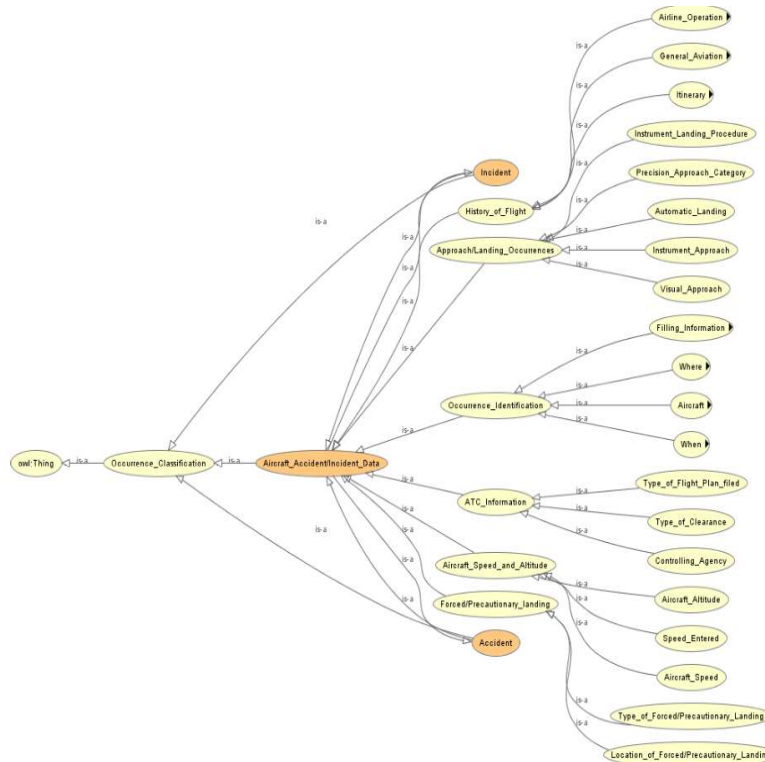


Figure 3: Accident and Incident Data Report and the Ontology Visualization, OWLViz

The accident and incident report manual was developed into the accident and incident ontology as shown in Figure 4. Every other data in the manual was categorized into the aircraft accident and incident data while the main entities which are the accident and the incident inherits the subclasses from the

aircraft accident and incident data. The accident class is disjoint with incident classes, which implies that the accident is different from the incident. In Figure 5, the incident class is shown to be disjoint with the accident class.

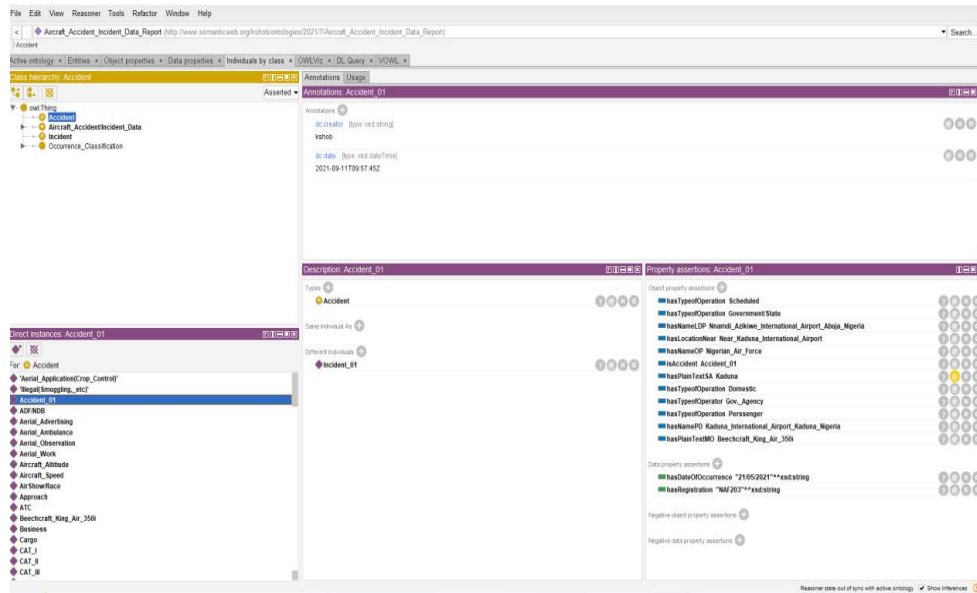


Figure 4: Occurrence Classification Accident Class

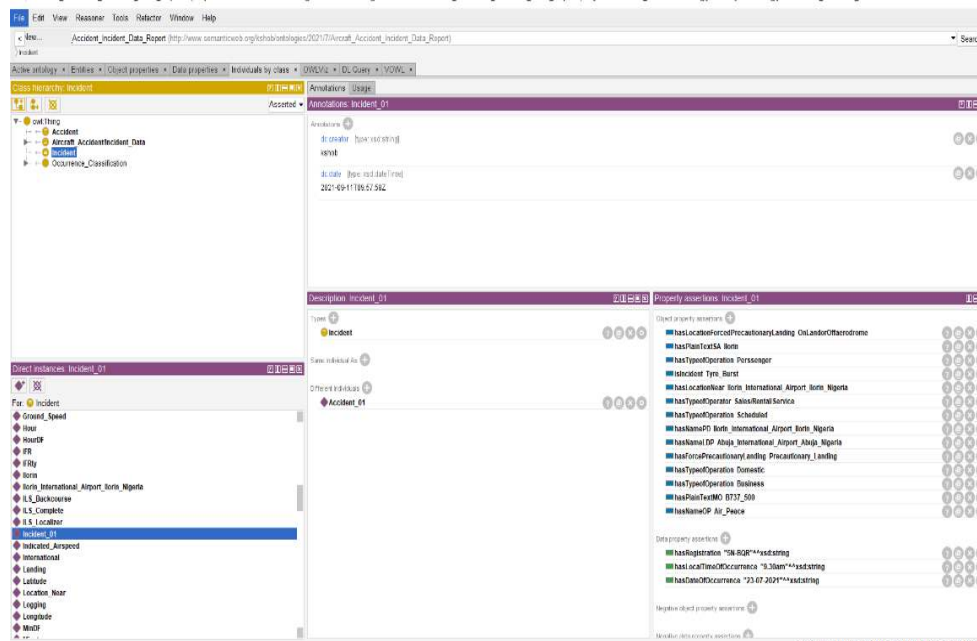


Figure 5: Occurrence Classification Incident Class

The data properties (Figure 6) connect an instance to a data value while the

object properties (Figure 7) maintain a link between two instances.

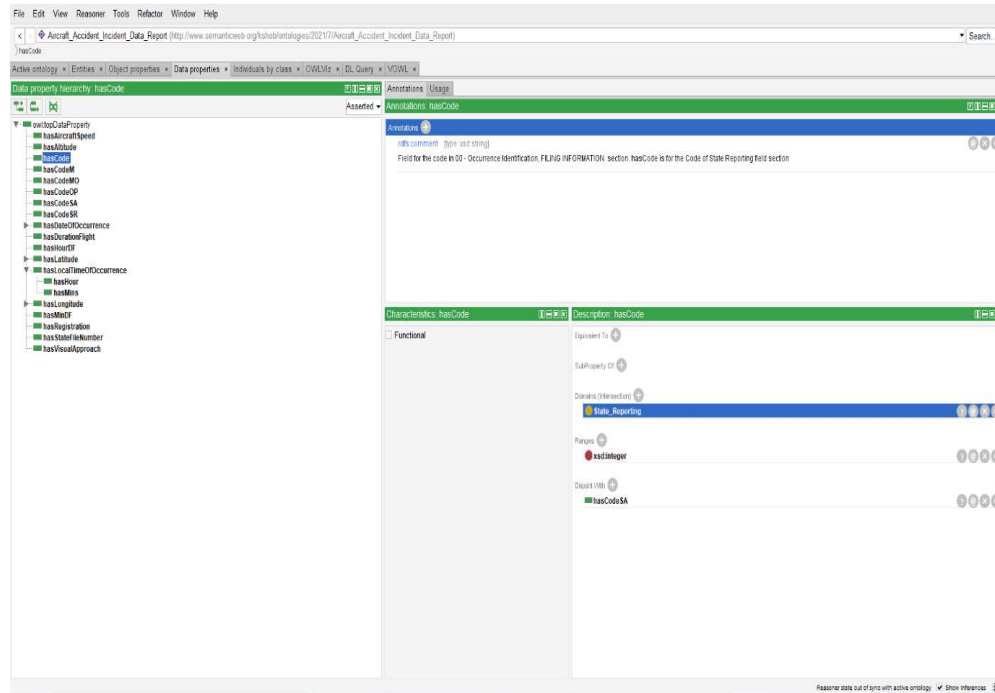


Figure 6: Data Properties of the Accident and Incident Ontology

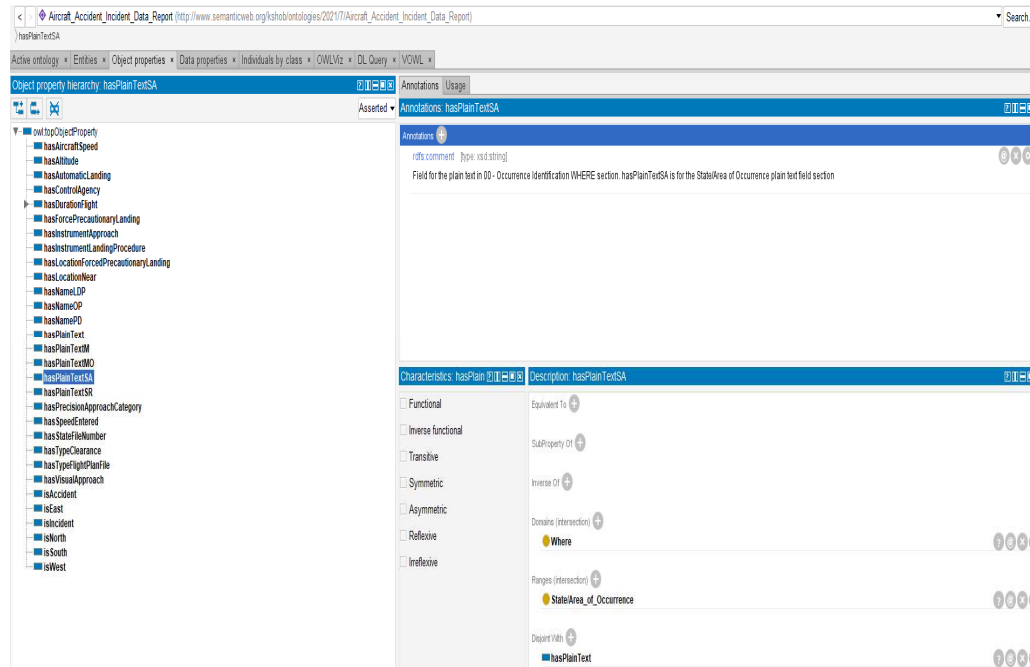


Figure 7: Object Properties of the Accident and Incident Ontology

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The instances of the accident and incident ontology are depicted in Figure 8. Instances are the main entities that the ontology works on. The class hierarchy which encodes all the main subheadings of the accident and incident manual is shown in Figure 9. For a meaningful knowledge base, inference has to occur, in protégé, this is achieved with the use of a reasoner, the comparison of the different types of reasoner

that can be used can be found in Table 2. Figure 10 shows the inference that was returned when the reasoner is started, the inferred classes are shown in yellow, this implies that the data in the knowledge base for that particular accident (Accident 01) are from the subclasses in the description box under the types heading highlighted in yellow (Figure 10). This also applies to the incident inferred model in Figure 11.

Table 2: Reasoning engines for OWL DL [Shobowale, 2018].

Reasoning Engines	Source	Query	Representation Language	Status	Algorithm
Pallet	Open (Clark and Parsia LLC)	SPARQL	OWL DL, OWL2 DL	Java based / well known	Based on Tableaux
Fact++	Open (University of Manchester)	-	OWL DL, OWL2 DL	C++ / well known	Based on Tableaux
RacerPro	Commercial (Racer Systems)	-	OWL DL	/ well known	Based on Tableaux
KAON2	Open/ Commercial	SPARQL	-	-	Not based on tableaux

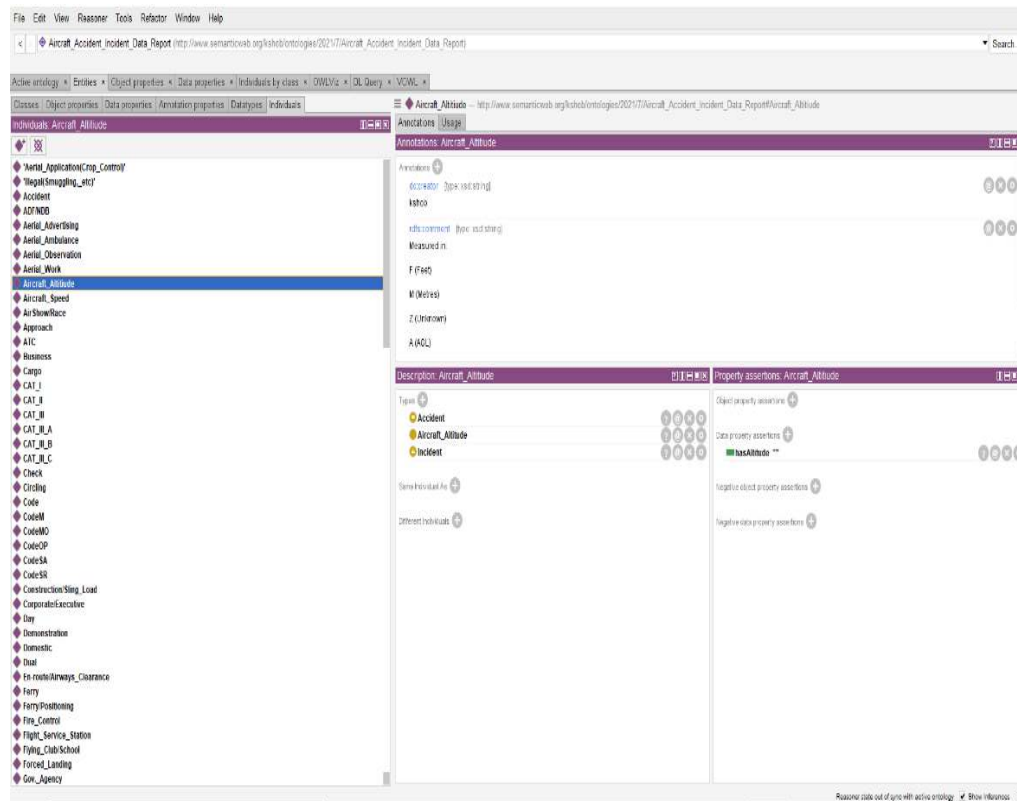


Figure 8: Instances of the Accident and Incident Ontology

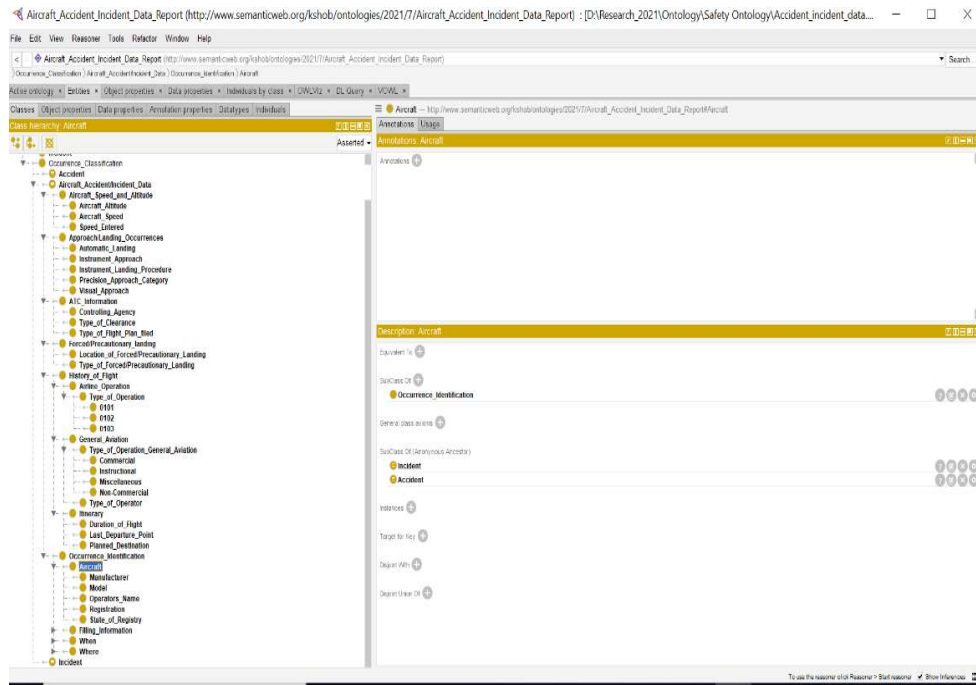


Figure 9: Class Hierarchy of the Accident and Incident Ontology

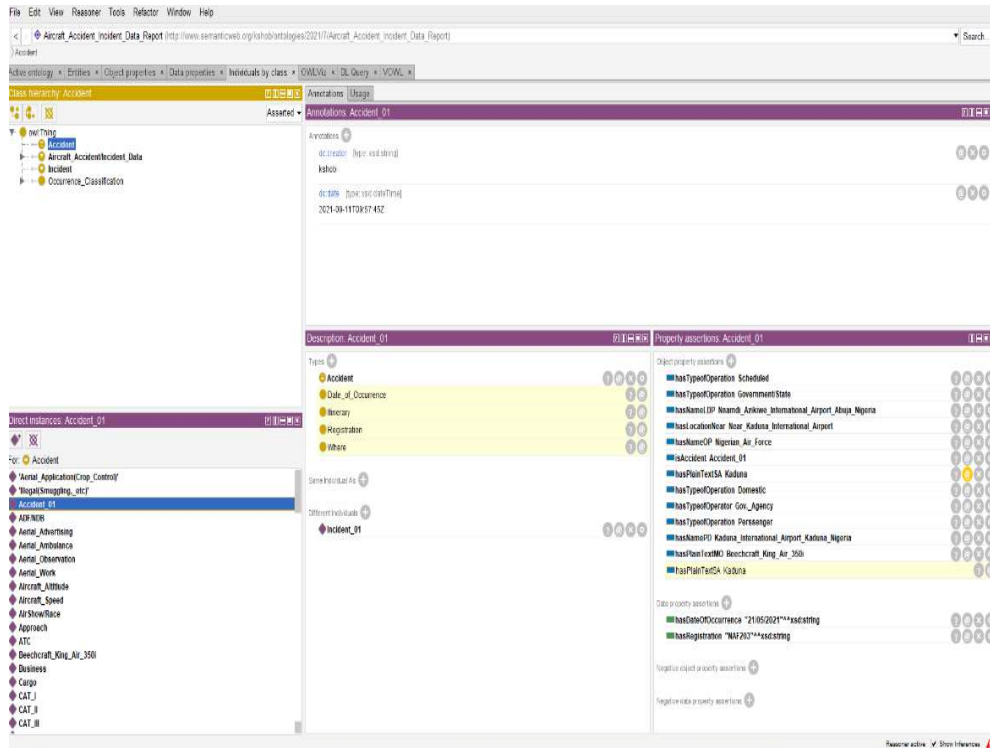


Figure 10: Accident Ontology Inferred Classes

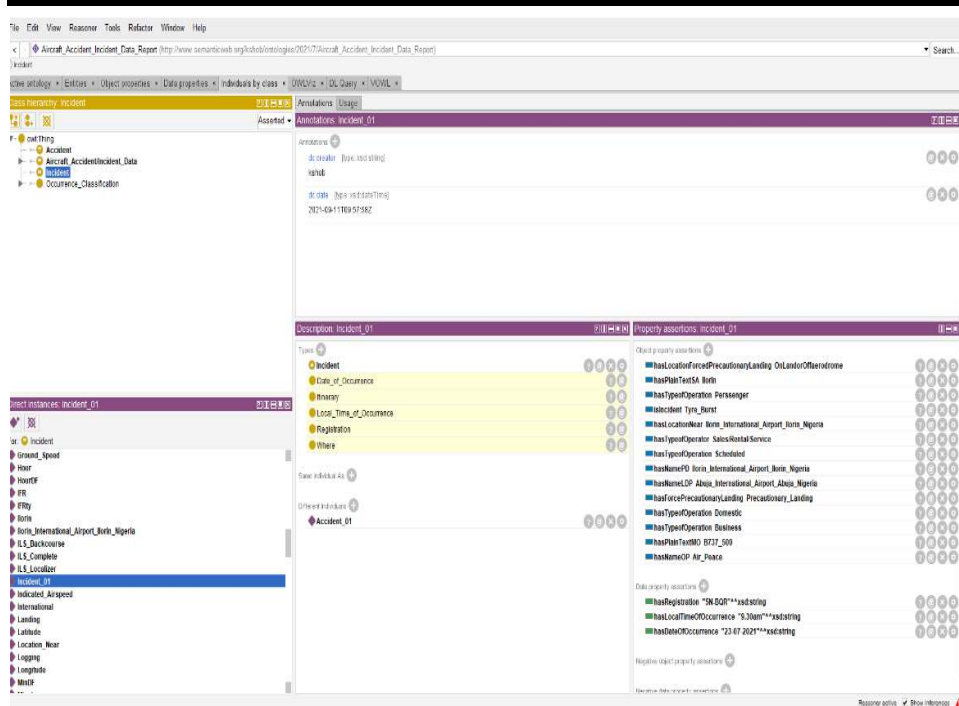


Figure 11: Incident Ontology Inferred Classes

CONCLUSION

Ontologies, owing to its expressiveness and interoperability nature can significantly optimize aviation accident and incident records through an ontological knowledge base on accident and incident of aircraft in the aviation industry. Trends in accident and incidents can be observed through pattern generation and proactive measures can be taken to drastically reduce the occurrence of such accident and incident. Future work of this research will be on the inclusion of the entire accident and incident manual and the automatic generation of accident and incident data from multiple sources such as data generation from text, internet and other online sources through tools such as natural language processing and to connect the ontological database through other application program interface for development of a software knowledge base systems.

REFERENCES

Aghdam M.Y., Tabbakh S.R.K., Chabok S.J.M. & Kheyabadi M. (2021). Ontology generation for flight safety messages in air traffic management. *J Big Data*, 8:61

Asim M.N., Wasim, M., Khan M.U.G, Mahmood W., & Abbasi H.M. (2018). A survey of ontology learning techniques and applications, *Database*, pp. 1–24

Chinedu, P. U., Nwankwo, W., Aliu, D., Shaba, S. M., & Momoh, M. O. *Cloud Security Concerns: Assessing the Fears of Service Adoption*

D. Aliu, S. M. Shaba, M. O. Momoh, P. U Chinedu and W. Nwankwo “A Computer Security System for Cloud Computing Based on Encryption Technique” *Computer Engineering and Applications* 10(1), February 2021,. (pp. 41-54).

Haendel M. A., Christopher G., Chute M.D., & Robinson P. N. (2018). Classification, Ontology, and Precision Medicine, *N Engl J Med*, 379, pp. 1452-1462.

Hughes P., Robinson R., Figueres-Esteban M., & Gulijk C.V. (2019). Extracting Safety Information from Multi-lingual accident reports using an Ontology-based Approach, *Safety Science*, 118, pp. 288-297.

Kondylakis H., Nikolaos A., Dimitra P., Anastasios K., Emmanouel K.,



- Kyriakos K., Iraklis S., Stylianos K., & Papadakis N. (2021). Delta: A Modular Ontology Evaluation System. *Information*, 12, 301
- Kremen P., Kostov B., Ahmed M.B.J., Plos V., Lalis A., Stojic S., & Vittek P. (2017). Ontological Foundations of European Coordination Center for Accident and Incident Reporting Systems, *Journal of Aerospace Information Systems*, 14(5), pp. 279-292.
- Ledvinka M., Lalis A., & Kremen P. (2019). Towards Data-driven Safety: An Ontology-based information System. *Journal of Aerospace Information Systems*, 16(1), pp. 22-36
- Milambo D., & Phiri J. (2019). Aircraft Spares Supply Chain Management for the Aviation Industry in Zambia Based on the Supply Chain Operations Reference (SCOR) Model. *Open Journal of Business and Management*, 7, pp. 1183-1195
- Otuka R.I., Tawil A.-R. & Al-Nemrat, A. (2017). Cloudysme: An Ontological Framework for Aiding SMEs Adoption of SaaS in a Cloud Environment. *Journal of Computer and Communications*, 5, pp. 86-112.
- Procedures Manual of Aircraft Accident/Incident Investigation. Accessed on 15th June, 2021 <https://www.civilaviation.gov.in/sites/default/files/Current%20Procedure%20Manual%20for%20Accident%20Investigation.pdf>
- Saeeda L. (2017). Iterative Approach for Information Extraction and Ontology Learning from Textual Aviation Safety Reports. *European Semantic Web Conference*, pp. 236-245
- Shobowale K.O. (2018). Ontology Knowledge Based System Tool for Technology Decision Support for Subsea Multiphase Pump, Unpublished PhD Thesis, Universiti Teknologi PETRONAS
- Su K-W, Yang C-H & Huang P-H (2016). The Construction of an Ontology-Based Knowledge Management Model for Departure Procedures. *Advances in Aerospace Science and Technology*, 1, pp. 32-47
- Talib A.M., Alomary F.O., Alwadi H.F., & Albusayli, R.R. (2018). Ontology-Based Cyber Security Policy Implementation in Saudi Arabia. *Journal of Information Security*, 9, pp. 315-333.
- Yang Z. & Qing L. (2011). Ontology Modelling and Semantic Retrieval for Aircraft Fault Knowledge. *Computer Engineering and Applications*, 16.
- Zhao Q., Li Q., & Wen J. (2018). Construction and application research of knowledge graph in aviation risk field, *MATEC Web of Conferences* 151, 05003