TriboOnto: A Strategic Domain Ontology Model for Conceptualization of Tribology as a Principal Domain

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Abstract. For many years, scholars have been interested in representation of knowledge and question creation. Ontologies have become increasingly important as the requirement for data to be described in a way that is understandable by people and computers develops. Tribology is an area where there are presently no ontologies, hence it was decided to construct one. Significant information and semantic linkages have been identified after a thorough examination of the topic. The ontology was visualised in Protégé then in OWL format. The suggested ontology was found to have an effective reuse ratio of 0.944.

Keywords: Domain ontology · Ontology modelling · Tribology · Visualization · Knowledge modelling · Wear · Lubrications · Friction

1 Introduction

In the modern world, ontology is the most suitable paradigm for describing intelligence. The method of assembling data pertaining to a particular area of interest, defining and elaborating on their relationship, is known as ontology. Nevertheless, using crowdsourcing, real-life simple fields have been modelled. Ontologies that involve a great deal of specialisation, such as complex Domain Ontologies, cannot be modelled in that same way. It's important to create advanced definitions focused on structural and functional properties, as well as comprehensive understanding schemes. The domain Tribology is precisely represented in this ontology titled "TriboOnto," which is the scientific knowledge of contacting surfaces moving relative to one another, is sometimes known as the science of friction, wear, and lubrication. An ontology containing all of the domain's data was generated with the support of OWL (Web Ontology Language). The goal of this work is to develop and establish a Friction, Wear, and Lubrication ontology for representing tribology in terms of kinds and preventive methods.

Motivation: Tribology lacks an ontology that considered to be ideal, a critical concept in material research, encouraged researchers to use a semantic approach to better

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understand this area. From a conceptual and material-science viewpoint, no Ontology paradigm is developed for Tribology and Tribology-related concepts. The primary aim of this chapter is to develop a functional ontological model that allows for the organisation of friction, wear, and lubrication data concerning types and prevention methods in order to model a domain on tribology and thus enrich Material Informatics.

Contribution: Many techniques were carried out to investigate the domain, and important linkages and principles were identified. Ontology is important in web-based intelligence knowledge retrieval in this modern age of the semantic web. The current strategy takes 90primary classes into account. Protégé was used to build the hierarchical system. Information mapping was used for all initial subjects such as friction, wear, and lubrication since they serve as a reference in gaining an understanding of the topic.

Organization: The arrangement of the article will be as follows: Sect. 2 covers related work; Sect. 3 discusses ontology model and information processing for Tribology; Sect. 4 discusses ontology visualizations; Sect. 5 discusses ontology evaluation; and Sect. 6 examines the research's conclusion. A list of relevant workscan be found in the last section.

2 Related Work

Bhushan et al. [1] has provided almost every element of the subject, from the foundations of friction, wear, lubrication, and surface interactions to the developing topic of micro/nanotribology. Ludema et al. [2] elaboratedtribology in a way that helps get a better grasp of the subject which contains updated information on issues including surface characterisation and new advancements in the area and more information on rolling element bearings, as well as detailed descriptions of typical testing techniques, including diagrams and surface texturing for improved lubrication. Hutchings et al. [3] have highlighted about tribological fundamentals and the tribological reaction of all kinds of materials, including metals, ceramics, and polymers. Mang et al. [4] have stated about the types of lubricants and broadly explain about the Lubrication regimes which help us reduce friction and how it helps as to prevent from wear. Stachowiak et al. [5] have presented a notion of experimental technique in Tribology, where it offers an understanding of the tribometer utilised by current technology, which aids in determining the proper material for the correct location. Nasution et al. [6] have presented an already existing idea of ontology, as well as a mathematically based technique to producing a subject model that supports existence. In [7–14] semantic applications based on ontologies have already been explored.

3 Ontology Modelling and Knowledge Representation for Tribology

The field of tribology has been given its own ontology. It has relationships like "Strongly associated," "weakly associated," "is a part of," and "has a part of". The proposed Tribo ontology's architecture is represented by the top level, which has three main subclasses:

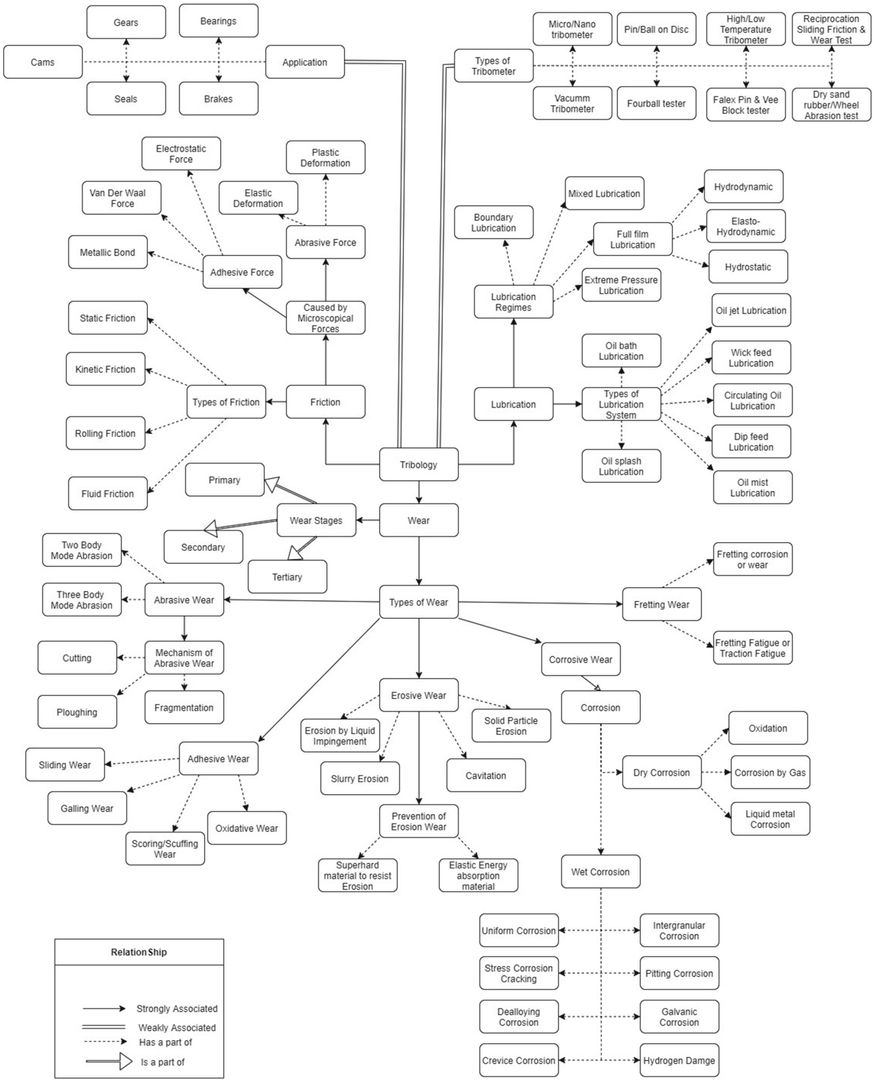

Fig. 1. Proposed ontology for tribology

Friction, Lubrication, and Wear. They are important and prominent tribological concepts, and they are strongly associated to the superclass "Tribology". Classes such as "Application" and "Types of Tribometer" are designed to evoke a memorable perception in the minds of readers, but they do not claim an irrevocable position in tribology discussions. Hence, they are connected as weakly associated (Table 1) (Fig. 1).

"Types of friction" and "Caused by Microscopical Forces" are two subclasses of the class "Friction." Friction is a significant phenomenon in tribology, and it is a crucial aspect in the development of the field of tribology. Static Friction, Kinetic Friction, Fluid Friction, and Rolling Friction are the four subclasses of the class "Types of Friction,"

Table 1. Some key topics are described using semantics

Keyword	Semantic implication
Friction	When one surface or object is moved over another, it encounters resistance which is known as Friction
Lubrication	Applying a substance to an engine or part, such as oil or grease, to reduce friction and allow for smooth motion
Wear	Wear is known as damage to the surface of one or more solid surfaces in contact with each other as a result of relative motion
Static friction	Individuals try to move a stationary object on the ground without deliberately inducing any relative displacement between their bodies and the surface they are on, resulting in static friction
Kinetic friction	A force that resists the motion of an item moving on a surface is known as kinetic friction
Rolling friction	The resistive force exerted by any surface against the rolling motion of any object moving over it, causing it to decelerate and gradually come to a halt, is known as rolling friction
Fluid friction	A force opposing the motion of an item moving on a fluid surface such as a liquid or gas is known as fluid friction
Abrasive wear	Hard asperities or hard particles slide over a softer surface, creating disruption at the interface due to plastic deformation
Adhesive wear	Adhesion, or more broadly, bonding happens at the asperity interactions at the surface, which are sheared by slipping, resulting in the separation of pieces from one surface, which may then bind to the other
Erosive wear	Erosive wear is characterised as material loss caused by the impact of fast-moving particles
Corrosive wear	Corrosive wear is a method of material deterioration that includes both wear and corrosion mechanisms.For example, Rubbing of rust
Fretting wear	A slight amplitude relative displacement between touching surfaces is known as fretting. A fretting damage or fretting wear is the term for the surface degradation caused by this movement

whereas the class “Caused by Microscopical Forces” has two subclasses. “Abrasive Force” and “Adhesive Force” are two forces which causes friction. “Adhesive Force” are minute force which causes opposing force in the object such as “Electrostatic Force”, “Van Der Waal Force” and “Metallic Bond” whereas “Adhesive Force” have “Plastic Deformation” and “Elastic Deformation”.

Two subclasses of the class “Wear” are “Types of Wear” and “Wear Stages.” Friction causes wear, which is an interesting aspect. The class “Types of Wear” has five subclasses: corrosive wear, erosive wear, abrasive wear, adhesive wear, and fretting wear, while the class “Wear Stages” has three. Wear is a collaboration in which we constructed types, mechanisms, modes, and some prevention methods. Lubrication is a significant preventative measure for reducing friction and preventing wear. It’s broken down into two sections: “Lubrication System Types” and “Lubrication Regime”. There are seven concepts in “Lubrication Regime,” and four in “Lubrication System Types”.

Bearings, Gears, Cams, Brakes, and Seals are the five subclasses of the term “Application”. They are the most frequent components used in rolling or sliding, and they assist us minimise friction in a wide range of applications. Before utilising the material for any purpose, it should be examined. There are a variety of ways to test the material’s tribology. There are many different types of tribometers being used nowadays. In this work, the term “Types of tribometer” is divided into eight subclasses, each of which represents a different form of tribometer.

4 Visualization

The process of visualising Ontology comes once it has been conceptualised. Ontology is represented using pictorial components utilising imaging tools. Patterns mostly in Ontology can be observed through visualisation. It decreases the amount of time spent searching for answers. It is advantageous because a vast volume of data can be analysed fast. Ontology may be seen using a variety of techniques. The visualisation is done with Web VOWL in this case. Web Protégé is used to convert the ontology to OWL format. Figure 2 illustrates the Ontology class hierarchy, Fig. 3 exhibits the object relationships, and Fig. 4 provides the topic network.

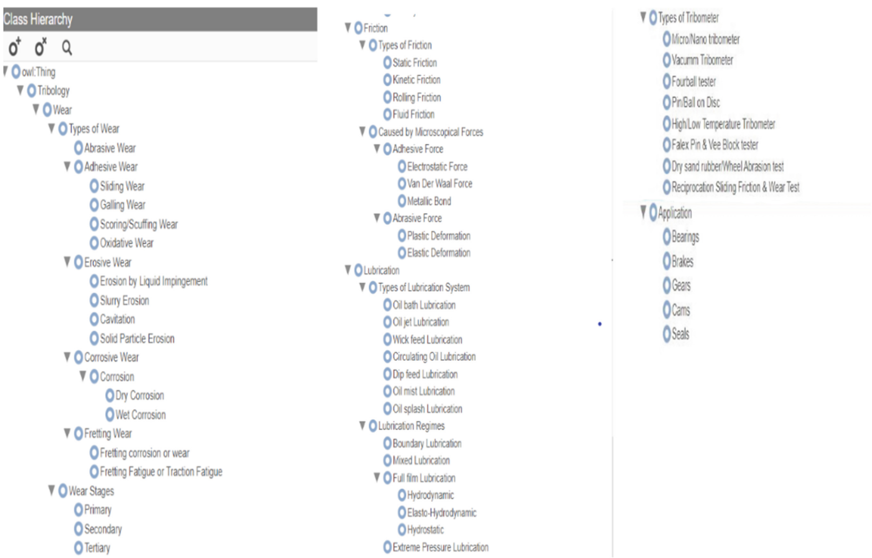

Fig. 2. Ontology class hierarchy

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 xmlns:owl="http://www.w3.org/2002/07/owl#"
 xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
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 xmlns:rdfs="http://wwww.w3.org/2000/01/rdf-schema#">
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    <owl:Restriction>
      <owl:onProperty
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ear"/>
      <owl:allValuesFrom
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riction"/>
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   </owl:equivalentClass>
  </owl:Class>
</rdf:RDF>
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Fig. 3. The objects' relationship

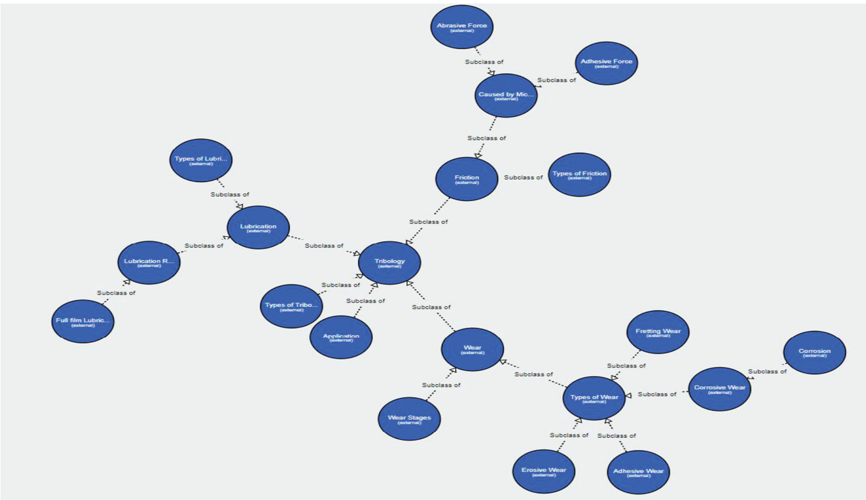

Fig. 4. Graph of entities

5 Evaluation of Ontology

Evaluation is the next phase in the ontological modelling process. Before using any ontology, it is evaluated. The evaluation was predicated on a variety of variables, with the reuse ratio and reference ratio being the most relevant. TriboOnto is quantitatively assessed by calculating the reuse ratio as 0.944. 90 classes and 6 properties of objects are available. That makes a conceptual ontology of TriboOnto (Table 2).

$$Reuse\ Ratio = \frac{No.\ of\ Reused\ Elements}{Total\ Elements\ in\ Domain}$$

$$Referenced\ Ratio = \frac{No.\ of\ reference\ Elements}{Total\ Element\ Reused}$$

Table 2. Ontology features that are quantifiable

Class	Sub-class	Attributes	Leaf class	Reuse ratio	Reference ratio
90	85	6	66	0.944	0

Table 3. Semiotics data approach

Qualitative metrics	Very high	High	Medium	Low
Accuracy	84	21	7	0
Clarity	91	14	7	0
Comprehensiveness	92	20	0	0
Consistency	104	8	0	0
Interpretability	101	8	3	0
Lawfulness	92	12	6	2
Relevance	109	3	0	0
Richness	97	7	8	1

The ontology analysis was conducted considering different parameters, including class count for all domain classes, sub class counts for all classified subclasses, leaf class count which includes all primary class knowledge, and number of attributes. Table 3 presents the conclusions. The ontology has already been reviewed by 112 domain experts using a semantic methodology. Accuracy, comprehensiveness, interpretability, consistency, lawfulness, clarity, relevance, and richness were among the eight parameters utilised in this assessment. Figure 5 represents the organized data of Table 3 in graphical representation. The voting from the table shows that the quality metrics have high scores from the participating students.

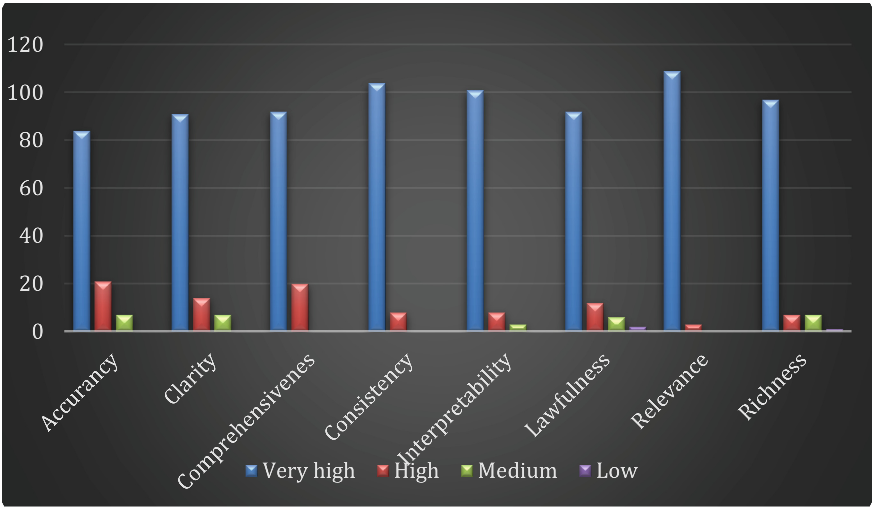

Fig. 5. Graph representation of semantic data approach

6 Conclusions

The developed ontology is based on material tribology. In order to view this ontology, Web Protege was used. The notion of TriboOnto was influenced by the lack of ontologies in the area of tribology. This has shown to be successful, as the grade of this ordered categorization has received an extremely positive response from a group of 112 persons who were chosen at random. Furthermore, the reuse ratio is a whopping 0.944, demonstrating TriboOnto's high quality. It gives you the tools you need to effectively express your data. It has shown to be effective in terms of establishing a platform for describing sharing and adaptable information, and it has a bright career in the fields of material informatics.

References

1. Bhushan, B., Ko, P.L.: Introduction to tribology. Appl. Mech. Rev. **56**(1), B6–B7 (2003)
2. Ludema, K.C., Ajayi, L.: Friction, Wear, Lubrication: a Textbook in Tribology. CRC Press (2018)
3. Hutchings, I., Shipway, P.: Tribology: Friction and Wear of Engineering Materials. Butterworth-Heinemann (2017)
4. Mang, T., Dresel, W.: Lubricants and Lubrication. John Wiley & Sons (2007)
5. Stachowiak, G., Batchelor, A.W.: Experimental Methods in Tribology. Elsevier (2004)
6. Nasution, M.K.M.: Ontology. In: Journal of Physics: Conference Series, vol. 1116, no. 2, p. 022030. IOP Publishing (2018)
7. Deepak, G., Santhanavijayan, A.: OntoBestFit: a best-fit occurrence estimation strategy for RDF driven faceted semantic search. Comput. Commun. **160**, 284–298 (2020)

8. Kumar, A., Deepak, G., Santhanavijayan, A.: HeTOnto: a novel approach for conceptualization, modeling, visualization, and formalization of domain centric ontologies for heat transfer. In 2020 IEEE International Conference on Electronics, Computing and Communication Technologies (CONECCT), pp. 1–6. IEEE (2020)
9. Deepak, G., Teja, V., Santhanavijayan, A.: A novel firefly driven scheme for resume parsing and matching based on entity linking paradigm. J. Disc. Math. Sci. Crypt. **23**(1), 157–165 (2020)
10. Deepak, G., Kumar, N., Bharadwaj, G.V.S.Y., Santhanavijayan, A.:OntoQuest: an ontological strategy for automatic question generation for e-assessment using static and dynamic knowledge. In: 2019 Fifteenth International Conference on Information Processing (ICINPRO), pp. 1–6. IEEE (2019)
11. Deepak, G., Priyadarshini, J.S.: Personalized and enhanced hybridized semantic algorithm for web image retrieval incorporating ontology classification, strategic query expansion, and content-based analysis. Comput. Electr. Eng. **72**, 14–25 (2018)
12. Varghese, L., Deepak, G., Santhanavijayan, A.: An IoT analytics approach for weather forecasting using raspberry Pi 3 model B+. In: 2019 Fifteenth International Conference on Information Processing, pp. 1–5. IEEE (2019)
13. Kaushik, I.S., Deepak, G., Santhanavijayan, A.: QuantQueryEXP: a novel strategic approach for query expansion based on quantum computing principles. J. Disc. Math. Sci. Crypt. **23**(2), 573–584 (2020)
14. Mukhopadhyay, M., et al.: Facial emotion recognition based on textural pattern and convolutional neural network. In: 2021 IEEE 4th International Conference on Computing, Power and Communication Technologies (GUCON), pp. 1–6 (2021). https://doi.org/10.1109/GUCON50781.2021.9573860