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Ontology Modeling of The Nymphalidae Family Butterfly on Java Island Using the Methontology

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***Abstract*—Indonesia, a mega-biodiverse nation with 53 national parks, including 12 on Java Island, hosts an immense variety of flora and fauna, particularly within the Nymphalidae butterfly family. However, the country's vast geographical complexity makes the understanding, classification, and management of information about these butterflies highly challenging, leading to fragmented and difficult-to-process data. This research aims to address this problem by constructing an ontology-based knowledge base to enable effective information reuse, integration, and semantic processing of Nymphalidae butterfly data from Java's national parks. The methodology employed the Methontology framework, which structured the development process into detailed stages: specification, conceptualization, formalization, implementation, and maintenance. The ontology was formally built using the Web Ontology Language (OWL) and the Resource Description Framework (RDF), with development and implementation carried out using the Protégé tool. Data integration and querying were facilitated through the application of semantic web standards, including SPARQL for retrieving information. The results yielded a structured semantic model for Nymphalidae butterflies in Java, comprising 7 classes, 4 object properties, and 4 data type properties. A critical evaluation using the HermiT Reasoner confirmed the ontology's logical consistency, proving the model to be sound. The primary contribution of this study is a validated, interoperable ontology that provides a standardized framework for organizing butterfly information, thereby facilitating better data sharing, integration, and knowledge management for biodiversity conservation and research efforts in Indonesia.**

***Index Terms*—Semantic web, methontology, nymphalidae, butterflies, ontology, Protégé tool.**

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I. Introduction

The geographical position of the tropical climate of Indonesia between Asia and Australia has resulted in a rich area of flora and fauna [1]. 10% of the total land area on earth has become a habitat for flowering plant species worldwide, while 12% is a habitat for mammals, 16% is a habitat for reptiles and amphibians, 17% is a habitat for birds, 25% is a habitat for fish, and 15% is a habitat for insects. There are 515 species of large mammals worldwide, of which 36% are endemic to Indonesia, consisting of 33 species of primates, while 18% are endemic to 78 species of parrots. 40% of butterflies in the world are endemic, consisting of 121 species, of which 44% are endemic to Indonesia [2]. That all needs information management, and this research manages to butterfly information using ontologies. The semantic ontology of the Nymphalidae family of butterflies can develop a comprehensive knowledge of butterflies.

One of the most diverse faunas in Indonesia is the butterfly. Currently, there are 2,000-2,500 butterfly species in Indonesia, and 640 of them are found on the island of Java. However, the estimates above may not represent the whole because there are still many areas that have not been studied. Java Island has 12 national parks with scattered butterfly species; for example, Baluran National Park has 63 butterfly species [3]. Butterfly information in Indonesia is undocumented. Myanmar has taxonomy data for the Nymphalidae family butterflies in native biodiversity [4]. Vaghela used the pollard walk method for butterfly (Lepidoptera) diversity pattern in the Mangrol area of the Kathiawar Peninsula [5]. Yan et al. comparatively analyzed 105 mitochondrial genomes are gene features and based on mitogenome analysis is the phylogenetic relationship of the cosmopolitan butterfly family Nymphalidae (Lepidoptera) [6].

Integrating a library application with several other parties' library applications in multiple versions raises Semantic Conflict (SC) issues in loaded APIs and shadowed APIs with Java Programming. Wang et al. use 316 SC empirical issues to understand significant changes [7]. Varshney et al. developed a real-world semantic dataset on Uttarakhand Floods using a Universal Sentence Encoder (USE). These datasets are very important for the development of information systems to handle disaster situations quickly and on time [8]. Other study developed semantics by embedding design patterns into vectors simultaneously with natural language words. This is to overcome the possibility that there is no information on pattern design books, and running out of vocabulary due to the limited content of the books [9].

This research develops semantic ontology modeling of butterfly information using the Methontology methodological approach. Ontologies representing knowledge from information domain concepts are at the core of semantic to web technologies. The semantic web development without losing the good things of the web itself defines data networks for machine learning recognition. The semantic to web changes from a decentralized platform for display distribution (presentation) to a decentralized platform for knowledge distribution [10]. This researcher uses a research Methontology methodological approach to build an ontology based on OWL. Ontology modeling of Nymphalidae butterflies will provide a structured information web with semantics.

II. Literature Review

The research results showed that the Nymphalidae family consists of Melanitis leda (Common Evening Brown), Ypthima baldus (Common Fivering), Junonia lemonias (Lemon Pansy), Cynthia cardui (Painted Lady), Junonia almanac (Peacock Pansy), Junonia Orithya (Blue Pansy), Acraea violae (Twany Castor), Hypolimnas Misippus (Danaid Eggfly), Tirumala limniace (Blue Tiger), Hypolimnas bolina (Great Eggfly), Danaus chrysippus (Plain Tiger), Danaus genutia (Striped Tiger), Euploea core (Common Indian Crow), Byblia ilithyia (Joker), Euthalia nais (Baronet) [5]. Tian Yan et al. of the research results show that the Nymphalidae family is categorized as a monophyletic group: 1) Euthaliini (in Liminutetinae); 2) Melitaeini, Kallimini (in Nymphalinae); 3) Pseudergolini (in Cyrestinae); 4) Mycalesini, Coenonymphini, Ypthimini, Satyrini, and Melanitini (in Satyrinae); 5) Charaxini (in Charaxinae). Some tribes that show polyphyletic characteristics of Tian Yan are 1) Danaini and Euploeini (in Danainae); 2) Liminuteini (in Liminutetinae); 3) Nymphalini and Hypolimni (in Nymphalinae); 4) Lethini (in Satyrinae) [6].

In East Lombok Regency at Joben Eco Park, butterfly community data collection analyzed the butterfly diversity index using a purposive survey method with the Shannon Wiener formula. There are butterfly families consisting of the Papilionidae family (Papilio Memnon, Papilio demoleus, Papilio polytes, Graphium doson), the Nymphalidae family (Cupha erymanthis, Euploea core, Elymnias hypermnestra, Euploea leucostictos, Hypolimnas bolina, Hypolimnas anomalous, Juvenile Ideopsis, Junonia erigone, Junonia almanaa, Junonia iphita, Melanitis phedima, Melanitis leda, Mycalesis mineus, Orsotriaena medus, Neptis Hylas, Tanaecia palguna, Tirumala septentrionis, Tirumala hamate, Ypthima baldus), Family Pieridae (Catopsilia pamona, Eurema Hecabe, Delias sp., Leptosia nina), Family Lycaenidae (Leptotes sp., Jamides celeno) [11]. Nurliza et al. studied butterfly species from TNGP in the Lowland Granite Forest, Freshwater Swamp Forest, and Alluvial Forest ecosystems as well as the potential for butterfly insectariums [12].

Another result proposed expanding the identifier abbreviation by utilizing semantic relationships and transfer expansion to overcome inaccurate or limited identifiers [13]. Simple Protocol and RDF Query Language (SPARQL) queries dedicated to data semantic in the form RDF (Resource Description Framework) by Banane and Belangour converted into Hive programs, Pig programs, or Spark scripts according to the user's choice [14]. Other researcher in semantic used a hybrid method to compare the execution each target function similarity with the runtime information migrated from the reference function, and then execute the binary function with test cases to the reference function [15]. Meanwhile, others developed a third of knowledge type resource (Hybrid) with variations of the RDF triples structure, semantically linking ontological concepts with their linguistic parts for linguistic expression of the dynamic nature and conceptual knowledge [16]. The publication technique that links data using standard web technology is often called linked data. The creation of linked data follows the principles recommended by Tim-Berners-Lee [17].

Ontology represents knowledge from concepts set in an information domain and the relationship between these concepts. The ontologies present information semantically, organizing and mapping a collection of information resources in a systematic and structured manner. Ontology formally describes the various concepts of a domain and the interrelationships between these concepts [18], [19]. Other research presented an analysis of the development of an intelligent system to represent knowledge about wild, cultivated, and protected flora in Bulgaria. The ontology is processed according to plant taxonomy and botanical scientific sources, and includes various data on plants, such as biodiversity, monitoring, and protection.

A. Semantic Web

Tim Berners-Lee at al. first developed the Semantic Web in 2001, which was published in the Scientific American magazine. World Wide Web Consortium (W3C) is responsible for the semantic web and infrastructure development [20]. The semantic to web is a web that knows the meaning of the entities in the web [21]. The semantic to web on the web version 3.0 represents efficient data on the World Wide Web, or global database integration [22].

The semantic to web facilitates the reuse and sharing of data across apps, companies, and community boundaries by providing a standardized foundation. Annotation to semantic is the act of appending supplementary metadata to existing material. The defining ideas of the semantic to web states that software agents need to link web resources with information to utilize them. Multiple stakeholders enhance interoperability by exchanging information in a shared and clear interpretation. Applications must possess the capability to exchange information and interpret the transmitted data consistently, guaranteeing its reuse without any mistakes or loss of data [23].

W3C issued a language recommendation for ontology computing. The language consists of RDF, SPARQL, JavaScript Object Notation for Linked Data (JSON-LD), OWL (Web Ontology Language), The Shapes Constraint Language (SHACL), and Simple Knowledge Organization System (SKOS) [24].

Berner states that OWL maps the relationships among conceptual objects, classes, and properties of web content by providing facilities for machine interpretation. OWL is a

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combination of OIL and DAML. The OWL vocabulary relies only on DAML and RDF Schema does not yet have complete semantics [17]. The W3C requires and defines the OWL Specification as an ontology description language for the Semantic Web [25]. Breitmen describes the requirements for OWL: language design must be compatible with XML, follow description logic, and support ontology vocabulary [26].

B. Methontology

Methontology is for developing ontologies that suggest representing concepts as a series of intermediate representations (IR) and creating ontologies using translators. Ontology engineering necessitates the establishment and standardization of an ontology lifecycle, along with the methodologies and techniques that guide its evolution. The ontology framework makes it easier to make knowledge-level ontologies. It has four parts: a way to describe knowledge-level ontologies, a prototype-based development lifecycle, and a multilingual translator that automatically turns the description into multiple target codes. The ODE (Ontology Design Environment) is the specified environment for constructing ontologies using the Methontology framework [27]–[31].

III. Research Method

Methodology is a method of developing ontology originating from the development of chemical ontology at the University of Madrid Polytechnic. Methontology stages consist of specification, conceptualization, and implementation [27]–[30].

The ontology development method classifies the three main processes into several sub-processes. The management process consists of scheduling, control, and quality assurance sub-processes. The development process consists of specification, conceptualization, formalization, implementation, and maintenance sub-processes. The support process consists of knowledge acquisition, documentation, configuration management, and integration sub-processes [28]. Ontology development methods besides Methontology are EO, TOVE, KACTUS, CENSUS, OTK, UPON, and DOGMA. Methontology methodological approach has been supported by more than 1 tool, namely Protege-2000, OntoEdit, WebODE, and ODE [27].

A. Specifications

This stage as shown in Fig. 1, is the initial stage of developing the Nymphalidae Family Ontology, namely defining the requirements of the Nymphalidae Family by defining its goals and limitations. It is the initial stage in the development of the Nymphalidae Family Ontology, namely defining the needs of the Nymphalidae Family by defining its goals and boundaries. The research conducted a literature study of several international papers, books and observasi on the Nymphalidae Family in several national parks to define its goals and boundaries.

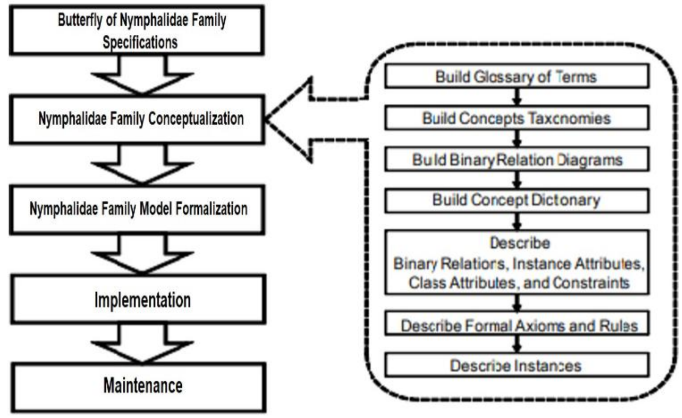

Fig. 1 Methontology methodological approach of the Nymphalidae Family [31].

B. Conceptualizasion

This stage defines ontology elements such as classes or concepts, properties, and individuals/instances. These elements are displayed conceptually in graphical form using the Unified Modeling Language (UML). This conceptualization consists of:

1) *Build a glossary of terms*
Identification of the Nymphalidae butterfly family in this literature study determines the domains and relevant terms, then the results are converted into ontology components of Nymphalidae butterflies in National Parks throughout Java Island.
2) *Build concept taxonomies*
Classification of the concepts and classes that have been identified in the glossary of terms.
3) *Build Nymphalidae butterfly binary relation diagrams*
Identify relationships and create relationships between concepts or classes that exist in the Nymphalidae butterfly ontology and map existing relationships so as to form the desired knowledge map.
4) *Build concept dictionary*
Identify all instances of each existing class and combine the instances of each concept, instances and class attributes, and ad hoc relations.
5) *The explanation of binary relations, class attributes, constraints, and instance attributes.*
Describing binary relations is the process of describing each existing relationship. Describing instance attributes is the process of describing the attributes of each instance in detail. Describing class attributes is the process of describing the attributes of each class in detail. Describing constants is the process of describing each existing constant.
6) *Describe formal axioms and rules*
Describing formal axioms is the process of describing the axioms to be used by specifying information consisting of names, natural language descriptions, and logical expressions. Describe rules is the process of describing the rules that have been identified.

7) *Describe instances*
This stage describes the information from each instance in detail. The results of the specifications and conceptualization were confirmed and discussed with several national park parties with several improvements.

C. Formalization

After the conceptualization is completed, the concept is formalized using Protégé 4.3. Input into the Protégé 4.3 application starts from the classes, subclasses, Individu/instances, Datatype Properties, semantic relations, and other components of the Nymphalidae Family Butterfly. Pengujian reasoning using Hermit Reasoner Test. Formalization also uses OntoEdit, WebOde, and ODE.

D. Implementation

This stage implements the ontology into the system to be built. This stage loads the ontology of the Nymphalidae Family Butterfly into an ontology development program. Ontology building programs use Protégé 4.3, OntoEdit, WebODE, and ODE.

E. Maintenance

The maintenance stage updates the ontology of the Nymphalidae Family Butterfly that has been created. Regular updating of the ontology keeps the ontology valid.

IV. RESULT

The research on the ontology requirements specification of the Nymphalidae family butterfly is based on literature studies, observations, and interviews in national parks on Java Island. Ontology development requires a Requirements Specification consisting of the Domain, objectives, scope, intended end users, and formalization of the ontology so that funds are directed according to needs. The result ontology requirements specification at this stage is like Table 1.

Table 1.
Ontology Requirements Specification

Item	Specifications
Domain	Nymphalidae family butterfly.
Purpose	Provision of structured information on Nymphalida family butterflies in national parks on the island of Java.
Scope	(1) Genus, (2) Species, (3) The location where the butterfly was found, (4)The height at which the butterfly is found, (5) Biome, and (6) Ecosystem.
Intended End-user	Academics and researchers
Formalization language	OWL

A. Conceptualizasion

This stage creates a conceptual model of the knowledge domain and the boundaries that have been set to create relationships between classes. The knowledge domain used is the ontology of the Nymphalidae family of butterflies. Ontologies have components consisting of classes, properties, ranges/values, and data types. Research before the conceptual model development made a list of object properties and a list of datatype properties as shown in Table 2 and Table 3. The results of determining the classes in Tables 2 and 3 are then carried out by research into the relationships between these classes according to their semantics. The conceptual model development for the butterfly family Nymphalidae in the form of an ontograph is shown in Fig. 2.

Table 2.
List of Object Properties Ontology of The Nymphalidae Family Butterfly

Class	Object Property	Range/Value
Genus	hasSpecies	Species
Species	in NationalPark	NationalPark
Species	inBiome	Biome
Species	inEcosystem	Ecosystem
Species	inHeight	Height
NationalPark	inLocation	Provinsi
NationalPark	hasBiome	Biome
NationalPark	hasEcosystem	Ecosystem

Table 3.
List of Data Type Properties Ontology of The Nymphalidae Family Butterfly

Class	Datatype Property	Range/Value
Genus	Name	String
Species	Name	String
NationalPark	Name, Address, Phone	String
Province	Name	String
Biome	Name	String
Ecosystem	Name	String
Height	Height	Int

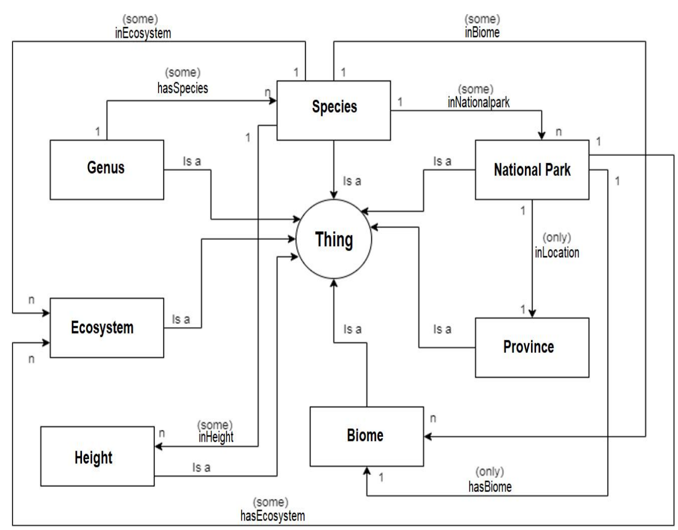

Fig. 2. Nymphalidae family butterfly binary relation ontology diagram.

Implementation of the results of the relationships between classes in Fig. 2 uses the Protégé 5.5 tool by displaying the Ontograph as seen in Fig. 3.

B. Formalization

Formalization of ontology design conceptual uses OWL-based Protégé 5.5. Formalization ontology in conceptual design develops hierarchies of object properties, data properties,

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classes, and individuals or instances. The following are the results of the formalization process:

1) *Class*

The Nymphalidae family butterfly domain consists of 7 classes, namely Genus, Species, National Parks, Provinces, Altitudes, Biomes, and Ecosystems. Figure 4 is the formalization class using Protégé 5.5.

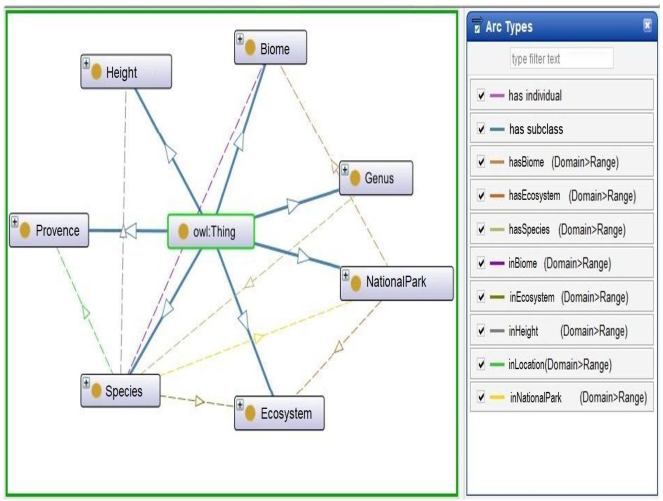

Fig. 3. Nymphalidae family butterfly ontology ontograph.

Fig. 4. Nymphalidae family butterfly ontology classes.

2) *Property*

The ontology property has two types of property usage, namely object properties and datatype properties. The object property functions to connect two classes. Ontology Nymphalidae butterfly family property lists of object properties and datatype properties are in Tables 2 and 3. The formalization of object properties and datatype properties uses Protégé 5.5, as in Fig. 5 for ontology object properties and Figure 6 for datatype properties. The Figure 5 is the semantics between the butterfly ontology classes of the Nymphalidae family in Protégé.

3) *Individual/instance*

Each class has several individual/instances. For example, National Parks have instances consisting of Tropical rainforests, Grassland, Savanna, and Taiga biomes. Figure 7 shows individual or instant details of each butterfly class of the Nymphalidae family in Protégé.

Evaluation of ontology consistency uses a reasoner. The quality and correctness of ontology have an important role in semantic representation and knowledge sharing [33]. Reasoning ontology reduces information redundancy in the knowledge base and finds conflicts in knowledge content [34].

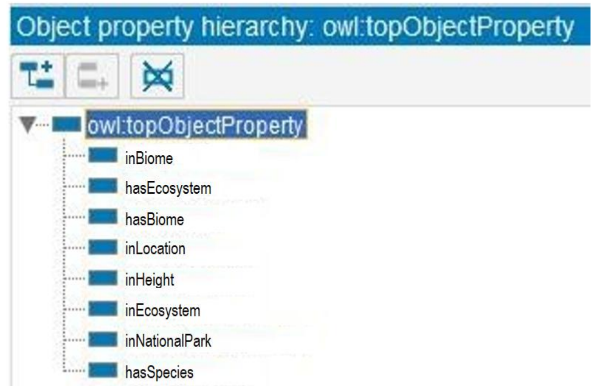

Fig. 5. Nymphalidae family butterfly ontology object properties.

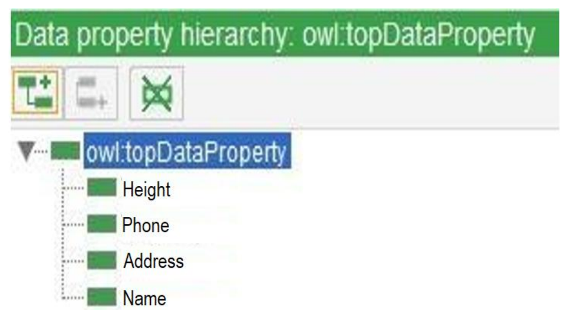

Fig. 6. Nymphalidae family butterfly datatype properties.

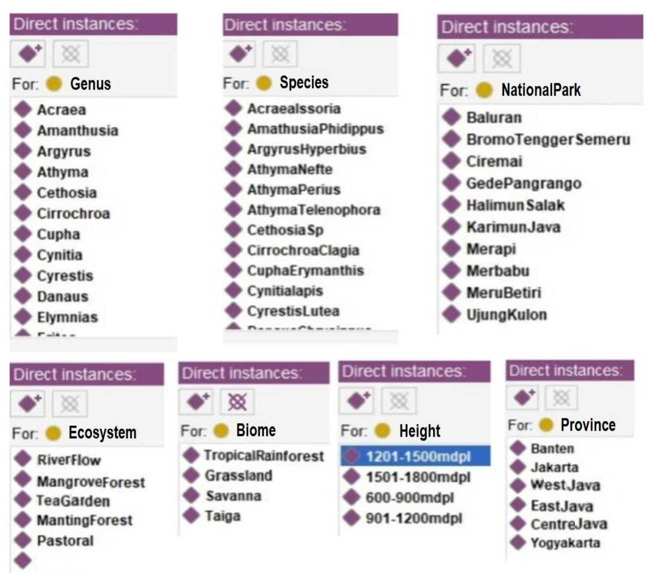

Fig. 7. Nymphalidae family butterfly instance class.

This study uses HermiT Reasoner to examine OWL files for class consistency and relationships between class identities, properties, and individuals. If an inconsistency is found in the OWL design, then the reasoner will mark an error and explain the error. The example in Fig. 8 shows that the Merbabu Butterfly subclass is consistent with the Species class. This shows that the Species class cannot be eliminated because it has consistent subclasses. It shows the consistency of semantic relations between classes or sub-classes.

Activation of the reasoner will produce object property inferences, data properties, and instances of the implemented reasoning rules' results. The results of this inference show whether the rules are in accordance with the expected ontology. The reasoner also functions to test the consistency of the logical descriptions implemented in the ontology. The difference between the components resulting in Protégé from reasoning or not is that the components resulting from reasoning will have a background and cannot be removed or edited. Figure 9 shows the inference results from the reasoning test. The inference results are examples of classification results using HermiT, taken from subclasses and property objects.

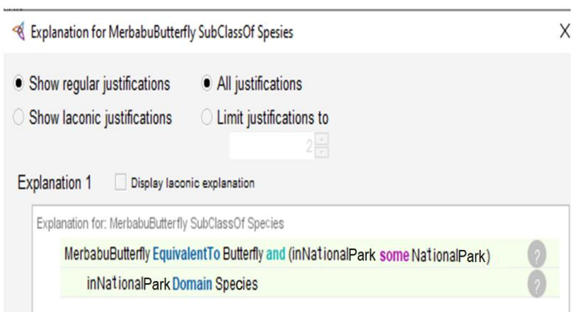

Fig. 8. Hermit reasoner test.

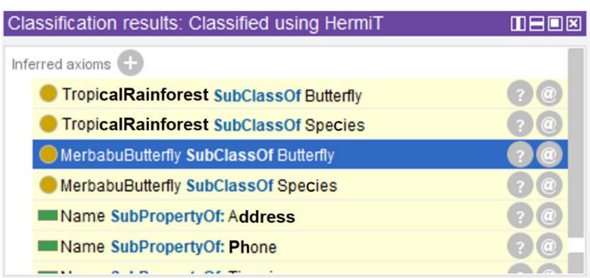

Fig. 9. Classifications results using hermit reasoner.

The appearance that classes and properties cannot be removed is the result of ontology consistency testing. HermiT Reasoner provides a classification of the rules in the ontology and ensures consistency so that they do not conflict with existing axioms. The results of the ontology consistency test using the reasoning process using the HermiT Reasoner tool show the inference results so that the ontology domain of the butterflies of the Nymphalidae family meets the conditions of a consistent ontology.

V. Discussion

The research on butterfly populations in the Mangrol of the Kathiawar Peninsula region used the pollard walk method. The recorded population in this area consists of the Nymphalidae, Pieridae, Papilionidae, and Lycaenidae families with quantitative and qualitative evaluation of community structure at four research locations [5]. A researcher collected and annotated eight Nymphalidae mitogenomes using a comparative analysis of 105 mitochondrial genomes. His research shows that the subfamilies Liberitinae, Apaturinae, Nymphalinae, Satyrinae, Heliconiinae, Charaxinae, and Danainae are monophyletic, while the Cyrestinae subfamily is polyphyletic. Phylogenetic and features gene relationships of the Nymphalidae Butterfly family based on mitogenome analysis for research on phylogenetic and population genetics relationships in this butterfly family [6]. Also, other conducted exploratory descriptive research to determine the butterfly community in Joben Eco Park, East Lombok Regency, using a purposive survey method with a combing technique following two observation lines. Analysis of the butterfly diversity index of 3.033 uses the Shannon-Winner formula, while analysis of the dominance index of 0.06 uses the Simpson formula [11]. Nurliza studied butterfly species from TNGP and the potential of butterfly insectariums in the Alluvial Forest, Lowland Granite Forest, and Freshwater Swamp Forest ecosystems. The benefits of research for learning biology are Classification of Living Creatures, Biodiversity, Ecology, and Animalia [12]. This research integrates the Nymphalidae butterfly family in 12 national parks on the island of Java in Indonesia for comprehensive scientific development.

Knowledge graphs automation is developed by exploiting semantic relationships and transfer extensions. Entity representativeness is the relationship of entities with a graph search for complete terms [13]. Banane's big data management research converts certain SPARQL queries into Hive programs, Pig programs, or Spark scripts according to user requirements to generate metamodels [14]. Integration of the Nymphalidae butterfly family in 12 national parks using semantics with the Methodology method to produce an ontology model for the Nymphalidae butterfly family. The formation of the ontology model uses Protégé 5.5 tools.

While research park is an initial study that analyzes methontology, it can serve as a foundation for other research that employs this methodology [32]. Current research uses only two stages of methontology [30], where development includes specification, conceptualization, formalization, and implementation. While post-development only covers maintenance, for pre-development, it is not done as density research.

VI. Conclusion

The Nymphalidae family butterflies ontology has 7 classes, 4 object properties, and 4 data type properties in Java Island National Park. The ontology development helps academics or researchers who need information related to butterflies. Another result of this research is a dataset on butterfly information, which facilitates the process of developing an integrated ontology in a system.

This research proves that the methontological approach can be applied to the ontology modeling of the Nymphalidae family butterfly on Java Island, which refers to the methontology stages proposed by [30], i.e., for different research domains that have adjustments at each stage. Overall, the development of the Indonesian butterfly ontology is one of the first attempts to represent related knowledge in a standardized format.

Butterfly ontology modeling often poses challenges, one of which is the difficulty in identifying and categorizing butterfly species that have a wide variety of patterns and high levels of similarity. As for Convolution Neural Networks (CNN) techniques and other deep learning techniques, they can significantly improve at least the accuracy of butterfly image classification and make identification procedures easier for scientific and conservation reasons. The additional weakness of butterfly ontology modeling is the first, that integrating technologies like XML, RDF, and OWL into its ontology requires a deep understanding of interactions in semantic web contexts. Second, the introduction and maintenance of efficient metadata, including educational characteristics, is essential to promoting the distribution, exploration, and use of content.

Future work should assess and validate the established ontology to ensure that it includes pertinent topics and is consistent. Additionally, to enhance data interchange and interoperability, integration with other information systems is required. Regarding the application's growth, it might be the next step toward utilizing this butterfly's ontology for greater functional advantages as a point of reference for other pertinent studies.

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