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Utilizing Apache Jena Fuseki for Ontology-Based Smartphone Knowledge Representation

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Abstract— Background: Smartphones are a fundamental require for everybody since smartphones can offer assistance someone's work through different highlights and certain innovation contained within the smartphone. Some people's need for information about smartphones makes people confused in choosing smartphone products because there are many smartphone brands available on the market, as a result, many people still buy smartphones that do not suit their needs and preferences. That is why ontology-based knowledge representation is becoming increasingly important in the field of smartphone technology to improve data organization, data retrieval, and interoperability. **Objective**: This research aims to develop a smartphone ontology using the Apache Jena Fuseki server which functions as a data collection tool and facilitates knowledge management about smartphones. **Methods**: This ontology was built using the methontology method, namely an ontology development method that is superior in providing a detailed description of each required activity. This smartphone ontology was developed using the Protégé 5.5.0 application which consists of 4 classes, 9 object properties, 15 data properties, and 92 individuals. **Results:** The research results show that the ontology built can help users search for smartphones that suit their criteria and needs. This research also succeeded in developing an android and semantic web-based application that allows users to search for smartphones more easily and efficiently, strengthening the benefits of the developed ontology in supporting smartphone purchasing decisions. **Conclusion**: The contribution of this research is to help customers, by providing recommendation the smartphone that best meets the requirements or best fits the given knowledge representation.

Keywords— Ontology; Methontology; Smartphone Knowledge Representation; Apache Jena Fuseki

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I. INTRODUCTION

Smartphones are a fundamental require for everybody since smartphones can offer assistance someone's work through different highlights and certain innovation contained within the smartphone [1]-[2], [3]. The rapid growth of smartphones in society has an impact on people's increasing purchasing power. The rapid development of smartphones has increased people's purchasing control with existing criteria ranging from brand, price to features that prospective buyers must consider when buying a smartphone [4]. Some people's need for information about smartphones makes people confused in choosing smartphone products because there are many smartphone brands available on the market, as a result, many people still buy smartphones that do not suit their needs and preferences. On the other hand, smartphone brands and specifications are also increasingly diverse. As smartphone production increases significantly, users are often faced with complex choices [5]. The complexity of this choice arises because there are many brands and models of smartphones available on the market, making it difficult for potential buyers to choose a product that suits their needs, availability of funds and preferences [4-5]. Many people do not have sufficient knowledge about the specifications and features that are taken into consideration when choosing a smartphone, making it difficult to make a decision. From the problems above, the existence of a system that is able to provide knowledge to prospective buyers is very necessary in order to be able to solve problems by providing solutions that are tailored to their needs. On the other hand, the system must be easy to use and be able to provide appropriate search results.

The proposed solution is to apply an ontology-based knowledge representation model, which can be utilized in the development of a system capable of modeling metadata concepts and semantic context, which is useful in the process of model inference and rule preparation [8]-[9]. Ontology is also as a database that can be implemented and accessed via the symantic web with ontology as its main component [8-9] and android-based applications with the flutter framework which is a software development kit used to develop mobile-based applications such as android and iOS [11-12] which are capable of describe information about smartphones tailored to their needs. This will help potential buyers understand the characteristics and specifications of each product, so they can make more informed decisions that suit the buyer's needs and preferences. Protégé is used to create an ontology structure. Protégé is an open-source platform that provides a growing community of users with a set of tools for building knowledge-based models of domains and applications with ontologies [14]. Protégé stores ontologies in a variety of formats, including relational databases, UML, XML, and RDF. Apache Jena Fuseki is a Java-based framework that can be used to develop semantic web that supports RDF, Web Ontology Language

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(OWL), and Triple Store [13-14]. The Apache Jena Fuseki server is needed in developing a SPARQL server that can display RDF data and process SPARQL queries on HTTP [17] besides that Apache Jena Fuseki can be used as an endpoint. Apache Jena Fuseki is a powerful tool for managing and querying RDF data, making it a great choice for ontology-based knowledge representation in smartphones [15-16].

There are several previous studies that discuss smartphone selection/search or smartphone knowledge representation. Research conducted by [1] focuses on building an ontology model for smartphones to help users choose smartphones that suit their criteria. Ontology development is carried out using a methodology which involves several stages starting from specification, knowledge acquisition, conceptualization, integration, implementation, evaluation, to documentation. The ontology implementation was carried out using Protégé 5.5.0 software, which allows users to perform searches based on certain criteria using SPARQL queries. Other research was carried out by [20], by applying the Fuzzy C-Means and TOPSIS methods and producing an android smartphone selection reference system that was able to group smartphones into three clusters, determine the appropriate clusters and provide smartphone references to users. The research [20], [21] uses white-box testing which produces all functions of the software to ensure the system runs well. The use of ontology was also carried out in research [22] which described the design of an ontology-based recommendation system to recommend student internship places. The research [22] aims to integrate information from various sources based on a common hierarchical ontology with the aim of increasing efficiency and user satisfaction and providing appropriate recommendations to students. Research conducted by [23] produced a smartphone review information system that provides better service to customers, by providing more complete and objective information about smartphones being sold. The use of web scraping techniques and sentiment analysis through the SVM method makes this system able to collect and analyze data effectively, providing significant added value in the consultation and decision-making process by consumers. Another relevant research is research conducted by [24] which aims to help users make smartphone choices based on various criteria such as price, features and performance. Although the methods used are different, the ultimate goal of this research is to help users make better decisions regarding smartphone selection.

This research aims to build an ontology-based smartphone knowledge representation utilizing the Apache Jena Fuseki. Apache Jena Fuseki, a semantic web server developed by the Apache Software Foundation, offers a comprehensive platform for storing, querying, and managing RDF data, which is fundamental for ontology development [15]. By leveraging the capabilities of Fuseki, developers can create and maintain ontologies that capture the complex relationships and properties within the smartphone domain. This enables the representation of smartphone

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knowledge in a structured and interconnected manner, supporting advanced data retrieval, reasoning, and inference capabilities. The importance of using Apache Jena Fuseki in ontology-based smartphone knowledge representation lies in its ability to provide a robust and efficient platform for storing, querying, and managing RDF data, which is essential for ontology development in the smartphone domain. The method applied in this research is the Methontology method [25]. Ontology is able to explicitly represent a knowledge domain through a concept by providing meaning, properties and relationships to the concept so that it is collected in the knowledge domain and forms a knowledge base [22-23]. Next, the corresponding domain concepts are reflected by the ontology [28]. Ontologies bring knowledge that can be made explicit, formalizing the relevant basic views of the domain model and making the model machine-like able to be processed and interpreted [29]. The contribution of this research is to help customers/buyers, by providing recommendation the smartphone that best meets the requirements or best fits the given knowledge representation or criteria.

II. RESEARCH METHOD

The research method used in this research is the methontology method. The methontology method is a methodology for building ontologies that was proposed by Fernández-López, Gómez-Pérez, and Juristo in 1997 [25]. It is a methodology specifically tailored for developing ontologies in the context of the semantic web and knowledge engineering. The methontology method is a structured ontology development method that is used to build ontologies from scratch. Methontology is one of the ontology model development methodologies that have advantages related to the description of each activity that must be carried out in detail [30]. By using Methontology, the built ontology can be reused. Figure 1 shows the stages in the methontology method.

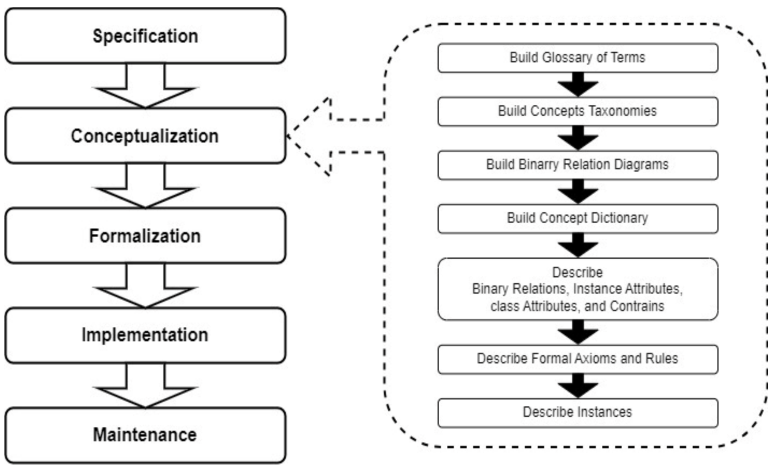

Fig 1. Methontology Method

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The following is an explanation of the methontology method in Figure 1:

1. Specification

The spesification activity states why the ontology was built, what its purpose is, how its use and who the end users, also where the aim of the ontology has to be identified [31]. The specification stage aims to produce informal, semi-formal, or formal ontology specification documents written in natural language, each using competency questions or intermediate representations .

2. Conceptualization

Conceptualization activities in methontology method organize and change something an informally perceived view of a domain into a semi-formal specification using a collection of intermediate representations (IR) based on these tabular and graphical notations understandable by domain experts and ontology developers. The result of the conceptualization activity is the ontology conceptual model.

3. Formalization

Formalization the activity of changing a conceptual model into a formal or semi-computational model.

4. Implementation

Implementation activities build computable models in an ontology language (Ontolingua, RDF Scheme, OWL, etc.). Implementation tools automated conceptual models in various ontology languages. Figure 2 shows the architecture of an ontology-based application development system for smartphones, which integrates Front End and Back End components to support application functionality that interacts with data in the form of RDF (Resource Description Framework). On the Front End, the application is built using the Dart programming language with the Flutter framework. Flutter was chosen for its ability to create cross-platform applications with high performance and attractive appearance, which allows applications to run on various devices such as Android and iOS with a single code base. This application, with its user-friendly interface, allows users to interact, for example, by searching for information about a smartphone based on certain criteria. This application sends HTTP requests to the Back End to process and retrieve relevant data from the server.

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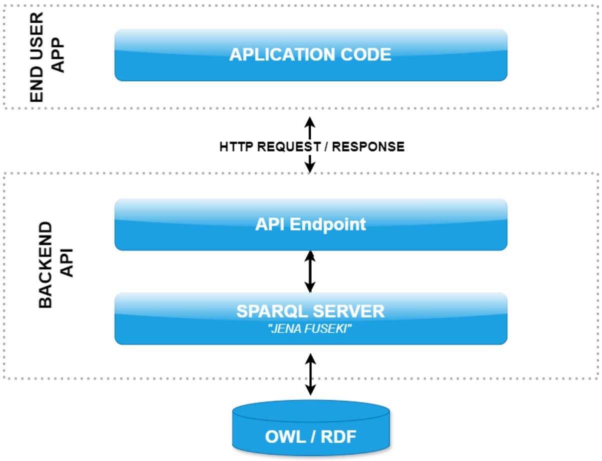

Fig 2. System Architecture

5. Maintenance

The maintenance activity updates and corrects the ontology if needed. At this stage, testing is also carried out on the ontology that has been built. Testing was carried out through several questions created with SPARQL queries whose results were displayed using the Apache Jena Fuseki server.

III. RESULT AND DISCUSSION

The results of developing an ontology-based smartphone knowledge representation using the methontology method are:

1. Specification

a. Domain ontology to be developed is a smartphone.

b. The aim of creating an ontology in this research is to help make it easier for customers/buyers to find information about smartphones that suits their needs.

c. The model to be created includes an ontology that explains the details of the smartphone being searched for, including price, brand, memory and screen size.

d. The contribution of this research is to help customers/buyers, by providing recommendations for smartphones that best meet the requirements or best suit the representation criteria or knowledge provided.

2. Conseptualization

Ontology conceptualization aims to organize knowledge gained during the process acquisition of knowledge. The conceptual model will then be converted into a model formal, which is then

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implemented with an ontology implementation language. A smartphone ontology conceptualization is built using methontology method. This ontology construction does not use all stages that exist as a result of certain stages of the component cannot be defined. Result of the conceptualization of smartphone ontology produces 4 classes as shown in Figure 3.

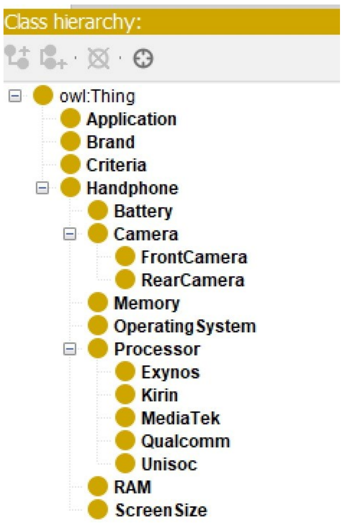

Fig 3. Class Hierarchy of Smartphone Ontology

3. Formalization

Ontology conceptual design has been done using methontology method then formalized using Protégé 5.5. On Protégé 5.5, every ontology parts are defined in accordance with the results of each stage of the task on methontology, where is the concept defined as a class, ad hoc binary relationships are defined as objects properties, class attributes and example attribute is defined as data type properties, and instances defined as an individual. Classes are formed in the smartphone ontology shown in Figure 3 consists of 4 classes namely Application, Mobile, Criteria and Brand.

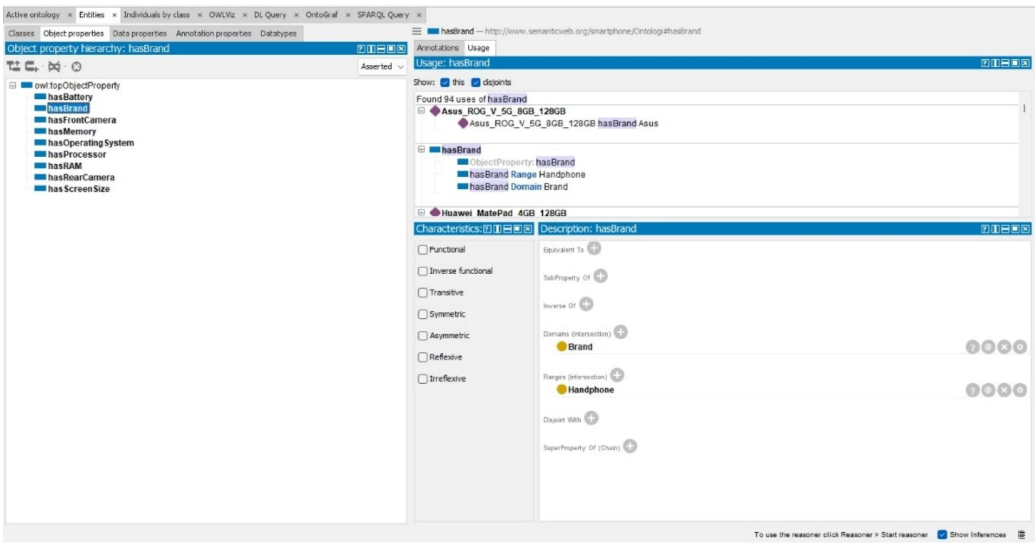

Fig 4. Object Properties of Smartphone Ontology

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Figure 4 shows the object properties. Object properties are relations connecting two or more classes. The smartphone ontology defines 9 components object properties as shown in Figure 4. An object property can be has inverse properties. If an object property connects *individuals a* and *individual b* then the inverse property is the opposite will connect *individual b* with *individual a*. Data properties are used for connect someone to concrete data values that have a data type. There are 15 data types properties in the smartphone ontology depicted in Figure 5. Individuals in Protégé 5.5 are representation of the example. Individuals from each attribute that each has classes are registered in the smartphone ontology implemented using Protégé 5.5. The individual of smartphone ontology can be seen in Figure 6.

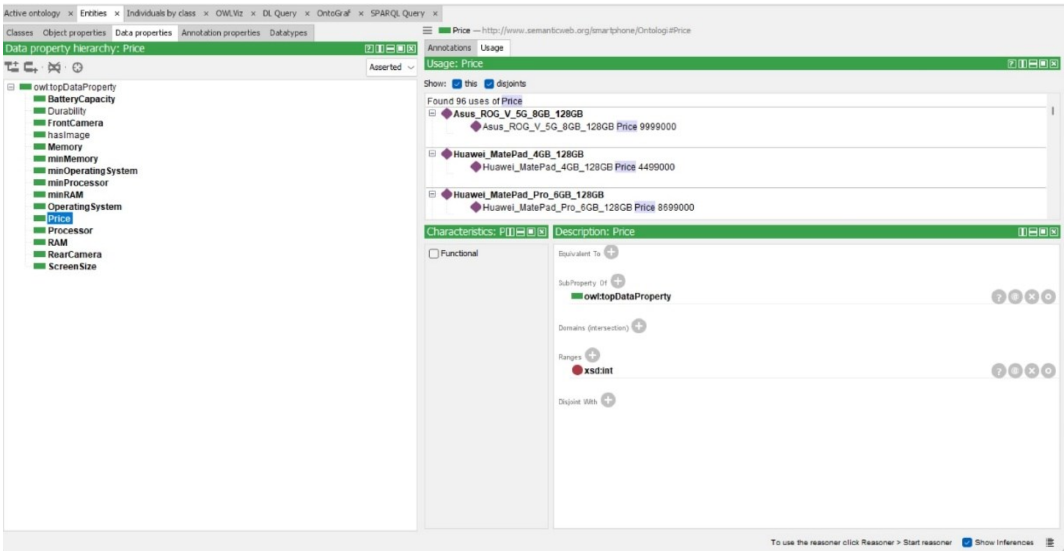

Fig 5. Data Properties of Smartphone Ontology

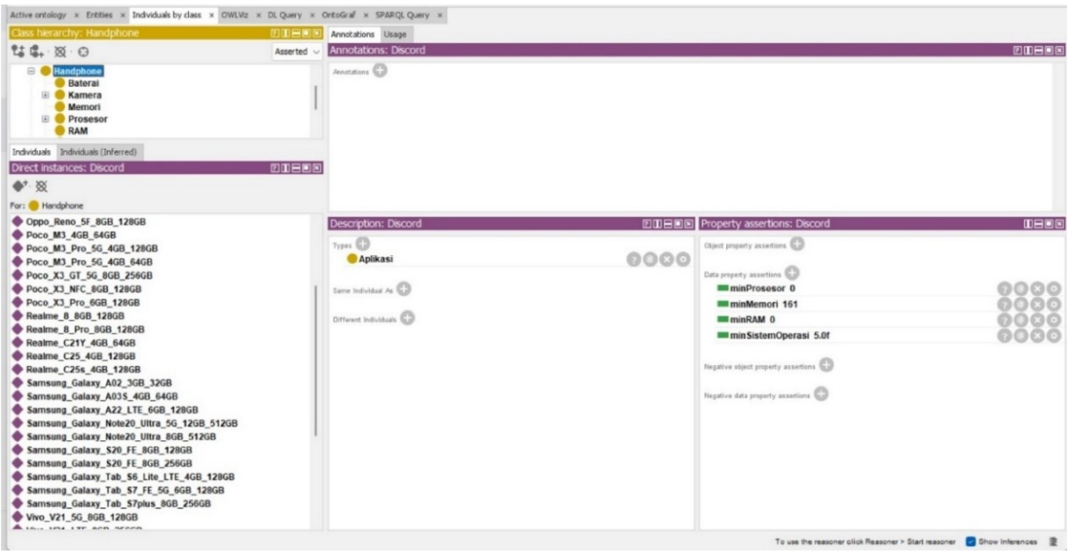

Fig 6. Individual of Smartphone Ontology

4. Implementation

At the implementation stage of the ontology model, researchers used the Protégé 5.5. application to build the ontology. Each part of the ontology is defined according to the results of

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each stage in the methontology method. After all classes, object properties, data properties are created, then create a smartphone instance which is implemented on the Apache Jena Fuseki web server and finally create an android mobile application interface and symantic web using the Dart programming language with the Flutter framework. Figure 7 shows the implementation results in the form of a mobile-based application interface and Figure 8 shows the web-based semantic application interface. Figure 9 shows the search results displayed on the mobile-based application.

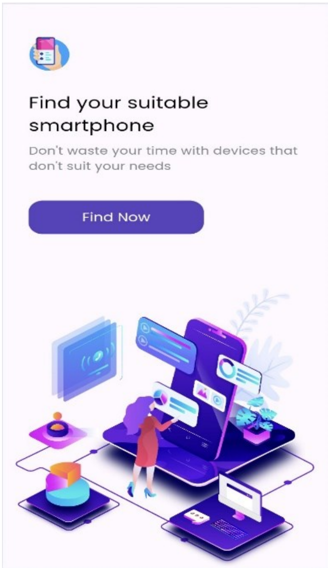

Fig 7. Mobile-based Application Interface

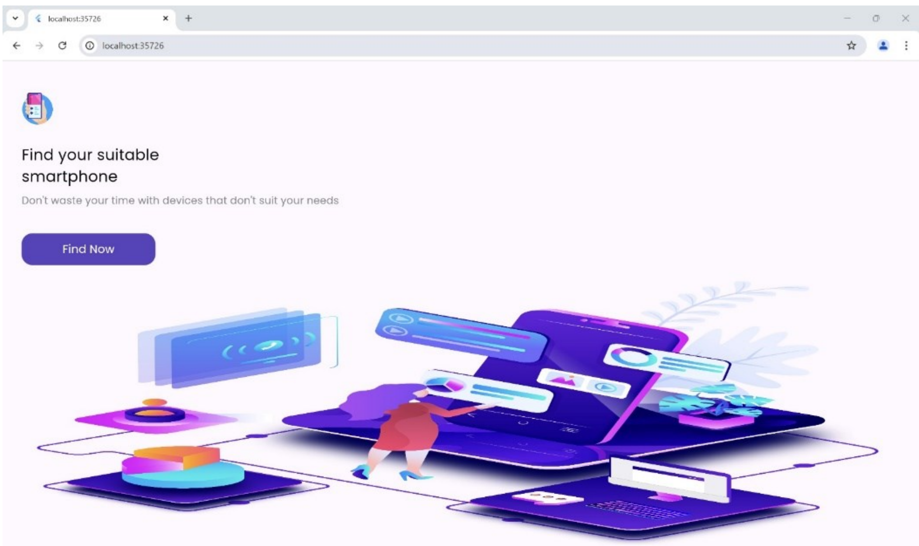

Fig 8. Semantic Web-based Application Interface

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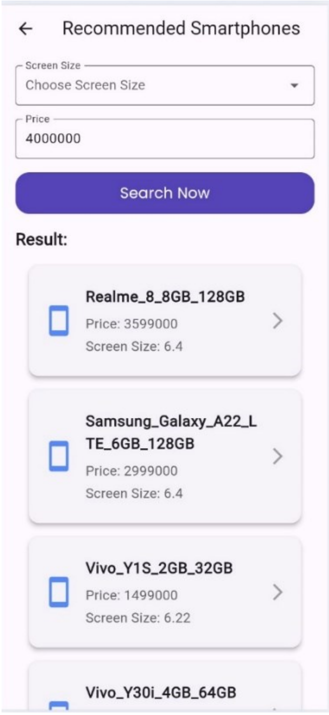

Fig 9. Mobile-based Search Results Display

5. Maintenance

In this research, the maintenance stage is carried out by testing the resulting ontology. This testing stage aims to reconsider the definitions used in the ontology being built, so that there are no errors in building relationships. Testing was carried out by making several questions with SPARQL queries [32] as shown in Figure 10, whose results were displayed using the Apache Jena Fuseki server.

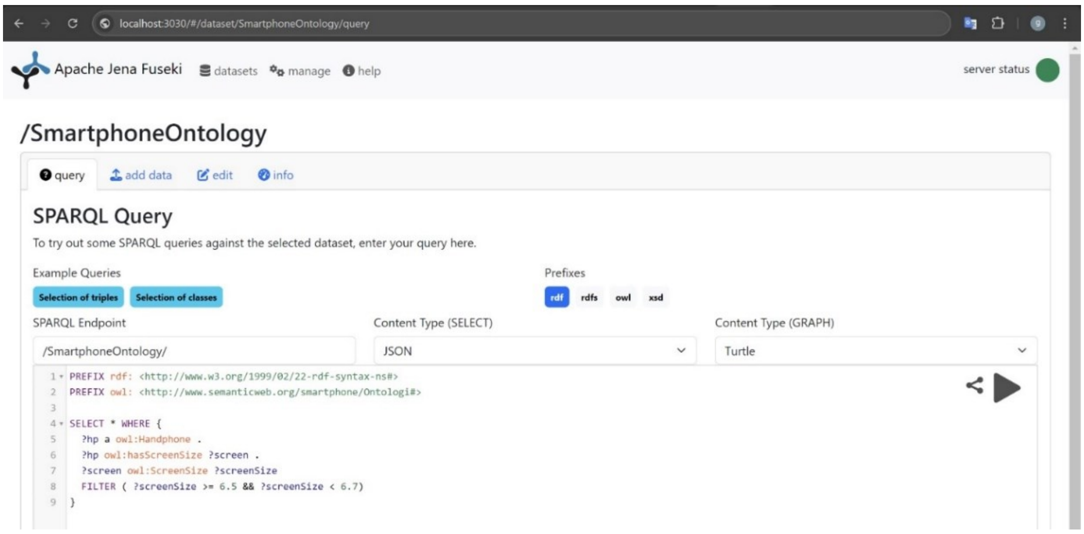

Fig 10. Testing with SPARQL Query

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a. First Query: Looking for a smartphone that costs under 2,000,000 as shown in Figure 11.

This SPARQL query is used to return all `smartphone` entities that have a price below 2,000,000. This query looks for data that meets the criteria that each `smartphone` (`?hp`) must have a `price value` property pointing to the price value (`?price`). The filter used ensures that only smartphones priced less than 2,000,000 will be displayed in the query results. All information about entities that meet these criteria will be displayed as query results.

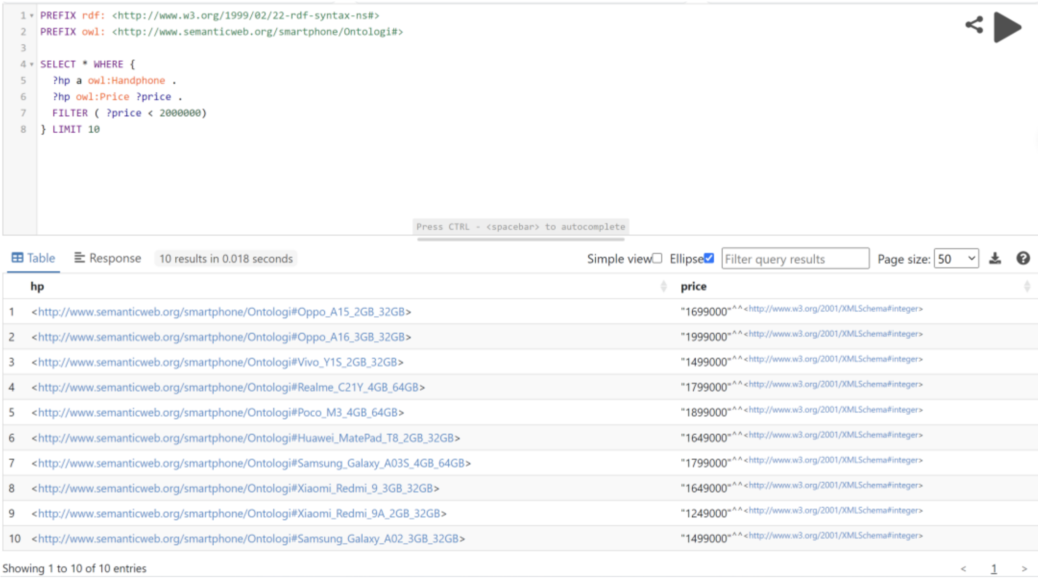

Fig 11. Results of Query SPARQL in Jena Fuseki for The First Query

b. Second Query: Looking for a smartphone whose screen size is less than 6.5 inches as shown in Figure 12.

This SPARQL query is used to return all `smartphone` entities that have a screen size of less than 6.5 inches (small screen size). In this query, the variable `?hp` represents the smartphone being searched for, which has a property `hasScreenSize` that associates it with the screensize (`?ul`) entity. From the screen size entity, the screen size value (`?Ulvalue`) is retrieved, and using `FILTER`, this query filters the results to only include smartphones with screen sizes less than 6.5 inches (small). The query results will include all variables related to the `smartphone` entity that meet these screen size criteria.

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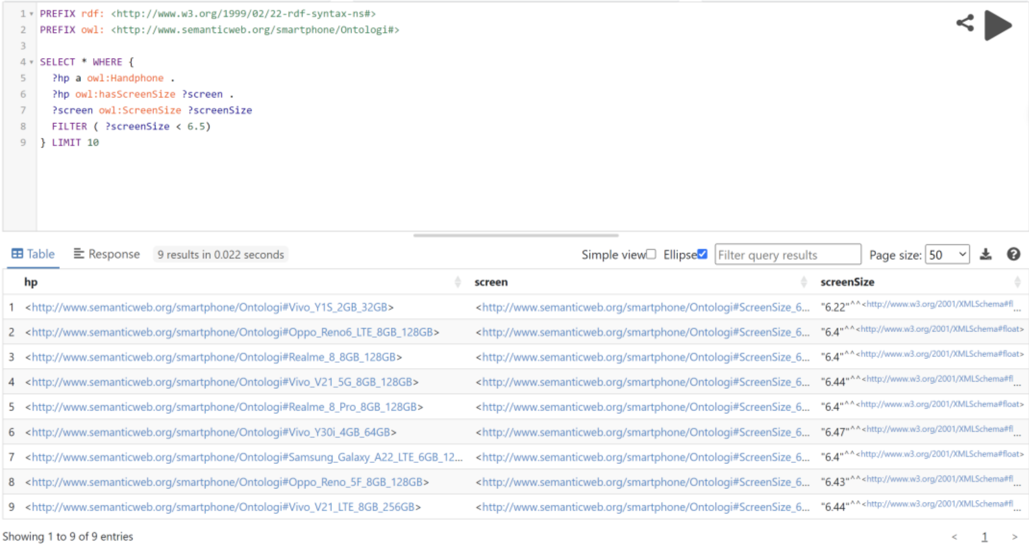

Fig 12. Results of Query SPARQL in Jena Fuseki for The Second Query

c. Third Question: Looking for a smartphone whose screen size is between 6.5 inches to less than 6.7 inches (medium size) as shown in Figure 13.

This SPARQL query is used to return all \`smartphone\` entities that have a screen size between 6.5 inches to less than 6.7 inches (medium size). In this query, \`?hp\` represents the smartphone being searched for and must have a \`hasScreenSize\` property that associates it with the screensize (\`?ul\`) entity. From the screen size entity, the \`ScreenSizevalue\` (\`?Ulvalue\`) property is retrieved, which is then filtered to only include screen sizes greater than or equal to 6.5 inches and less than 6.7 inches. The results of this query will include all variables associated with the \`smartphone\` entity that meet those criteria.

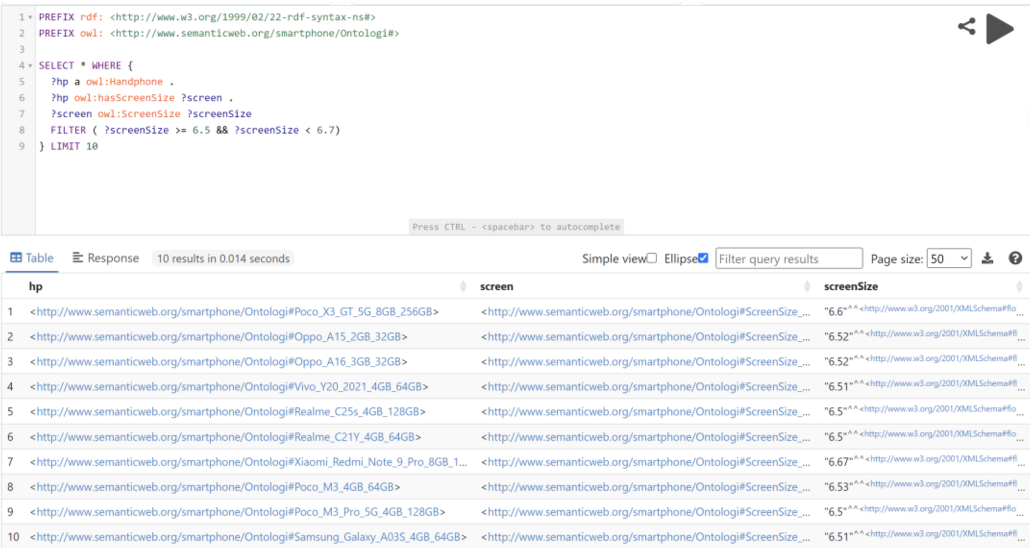

Fig 13. Results of Query SPARQL in Jena Fuseki for The Third Query

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d. Fourth Question: Looking for a smartphone whose screen size is at least 6.7 inches (large screen size) as in Figure 14.

This SPARQL query is used to display all `smartphone` entities that have a screen size of at least 6.7 inches (large screen size). This query looks for data that meets the criteria that each smartphone (`?hp`) must have a `hasScreenSize` relationship pointing to a screen size (`?ul`) entity. Then, from this screen size, the query checks the `ScreenSizevalue` property and filters the results to only include screen sizes (`?Ulvalue`) greater than or equal to 6.7 inches. All relevant information about entities that meet these criteria will be retrieved and displayed in the query results.

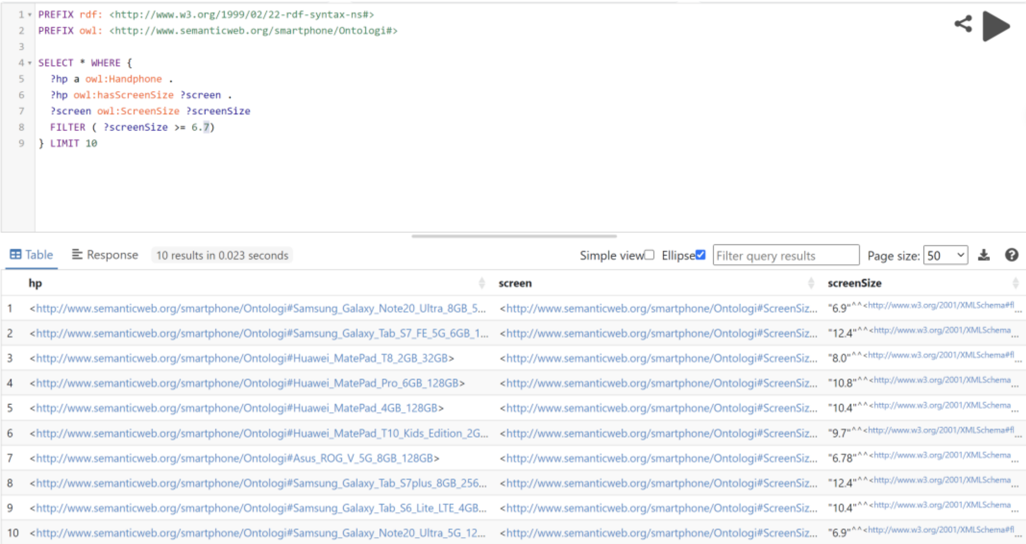

Fig 14. Results of Query SPARQL in Jena Fuseki for The Fourth Query

e. Fifth Question: Looking for a smartphone that has a screen size of less than 6.5 inches and a price under 2,500,000 as in Figure 15.

This SPARQL query is used to select all `smartphone` entities that have a screen size of less than 6.5 inches and a price below 2,500,000. In this query, `?hp` represents the smartphone being searched for, which has a `hasScreenSize` relationship with the screen size (`?ul`). From the screen size entity, the `ScreenSizevalue` (`?Ulvalue`) property is retrieved, which is then filtered to only include screen sizes less than 6.5 inches. Additionally, the query also checks the phone's `Pricevalue` (`?price`) property, and filters the results to only show smartphones priced under 2,500,000. The results of this query will include all variables related to the `smartphone` entity that meet both criteria.

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Fig 15. Results of Query SPARQL in Jena Fuseki for The Fifth Query.

IV. CONCLUSION

Smartphone ontology aims to collect data and facilitate knowledge management about smartphones. This research uses a methodological method, namely the ontology development method with the advantage of a detailed description of each activity that must be carried out. This smartphone ontology was built using the Protégé 5.5.0 application which consists of 4 classes, 9 object properties, 15 data properties, and 92 individuals. In this research, the ontology built can help users search for smartphones according to the required criteria and needs. Apart from that, this research also succeeded in creating an android and semantic web-based application that helps users search for smartphones more easily and efficiently. The limitation of this research is that there is no integration with online stores to accommodate purchase transactions through online stores. Therefore the next research development that can be carried out is to make the application interface more user friendly and add features so that it can be integrated into online stores.

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All authors have read and agreed to the published version of the manuscript.

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Data Availability: You can contact author's email whenever you need the explanation for this research.

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Informed Consent: There were no human subjects.

Animal Subjects: There were no animal subjects.

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