

SEMANTIC APPROACH FOR DIGITAL RESTORATION OF BALINESE LONTAR MANUSCRIPTS

Ida Bagus Gede Sarasvananda^{1*}, I Gde Eka Dharsika²,
I Wayan Kelvin Widana Saputra³, Welda⁴

^{1,2,3,4} Informatics, Faculty of Technology and Informatics, Institut Bisnis dan Teknologi Indonesia (INSTIKI)

email: sarasvananda@instiki.ac.id¹, ekadharsika@instiki.ac.id², kelvinsaputra024@gmail.com³, welda@instiki.ac.id⁴

Abstract

Balinese lontar manuscripts represent a cultural heritage containing significant historical, religious, and scientific values. However, their centuries-old age makes them vulnerable to damage. This research proposes a semantic-based digital restoration solution to address this issue. The semantic approach comprehends the meaning and structure of the lontar text, ensuring an accurate restoration process that preserves the original meaning. The development of the semantic-based digital restoration is built using the Design Science Research Methodology (DSRM). The system is equipped with data management features that accommodate new data, ensure accurate information updates, and maintain the integrity of relationships between entities. Testing through SPARQL query approaches and black-box testing indicates that data additions, deletions, and modifications function well without conflicts or inconsistencies. Moreover, the system performs as expected and is ready for use. The implications of this research suggest that semantic-based digital restoration can be an effective solution for preserving Balinese lontar manuscripts and similar cultural heritage.

Keywords : Digital Restoration, Lontar Manuscripts, Semantic Approach

Received: 11-09-2024 | **Revised:** 14-10-2024 | **Accepted:** 05-11-2024
DOI: <https://doi.org/10.23887/janapati.v13i3.84916>

INTRODUCTION

Bali is home to numerous cultural heritages that must be preserved, one of which is the Balinese lontar manuscripts. These manuscripts are a significant cultural asset, representing various aspects of life such as religion, art, science, and history. However, being centuries old, they are highly susceptible to damage caused by external factors like mold, humidity, termites, and human handling [1][2]. In this context, digital restoration serves as a solution to preserve the valuable information contained within the lontar manuscripts. By converting the physical manuscripts into digital formats, digital restoration ensures the continuity of this information and makes it more accessible to future generations [3][4].

Currently, government efforts towards the digital restoration of Balinese lontar manuscripts have begun with the creation of e-catalogs in PDF format. However, these efforts remain limited in terms of comprehensive data management and digital restoration. Some studies, such as those focused on semantic approaches for developing thesis advisor search

systems [5], using ontology to create tourist destination recommendations in Bali [6], developing ontology-based metadata models for Balinese lontar manuscripts [7], knowledge models have been applied to gambelan [8], and have been utilized across various fields for developing knowledge models [9][10][11][12], have been conducted. Yet, the implementation of a fully integrated semantic approach for managing lontar manuscript data has not been thoroughly explored.

This ontology provides a formalised specification that can be reused, making it easier to integrate data from multiple sources. [13][14].

This research proposes a semantic approach to support the digital restoration of Balinese lontar manuscripts. Integrating semantic technology into the digital restoration process will allow for more structured and organized data management, simplifying restoration efforts, preservation, and accessibility of the manuscripts for the general public and future generations [15][16][17]. The semantic approach aims to provide a richer, more meaningful digital representation, facilitating

access to and manipulation of the information for researchers, students, and the public.

Although there have been some attempts at digitizing cultural heritage, comprehensive studies integrating semantic approaches are still rare. A major gap lies in the lack of effective methods to retain the original meaning and context of Balinese lontar manuscripts during digitization. The novelty of this research lies in applying a comprehensive semantic approach to the restoration of these manuscripts, which is expected to significantly contribute to the preservation of cultural heritage. This approach will not only enrich the digital representation of the lontar manuscripts but also enhance the ease of manipulating and accessing the information, supporting efforts to preserve and disseminate the cultural values embedded in Balinese lontar manuscripts.

METHOD

This research employs the Design Science Research Methodology (DSRM), which consists of five stages: 1) problem identification and motivation, 2) objectives of the solution, 3) design and development, 4) demonstration and evaluation, 5) communication [5]. The stages of the DSRM method are illustrated in figure 1.

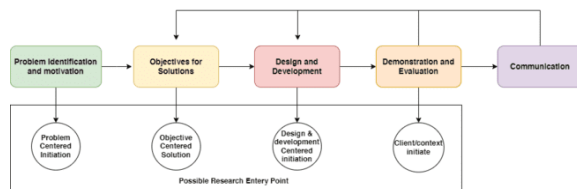


Figure 1. The Stages of the DSRM

The initial phase involves identifying specific problems encountered in the digital restoration of Balinese lontar manuscripts. These issues include the preservation of cultural heritage, ensuring the accessibility of lontar manuscripts, and addressing challenges caused by physical damage to the manuscripts. The motivation behind this research is to utilize semantic technology through ontologies to enhance the digital restoration process.

In the second phase, clear and structured objectives are established for the proposed solution. The main goal of this research is to develop a system using a semantic approach that supports CRUD operations (Create, Read, Update, Delete) for the digital restoration of Balinese lontar manuscripts. The

system aims to maintain the integrity and semantic richness of the original text while facilitating digital restoration and preservation.

The third phase involves design and development. In the design phase, an ontology model is created to represent the semantic structure of the lontar manuscripts. This ontology model was previously developed in the research "The Balinese Lontar Manuscript Metadata Model: An Ontology-Based Approach" [7]. The model captures essential elements of the lontar manuscripts, including entities such as manuscripts, authors, storage locations, origins, and relationships between these elements. The ontology is constructed using OWL (Web Ontology Language) and adheres to established standards. In the development phase, the system is designed to support CRUD operations, allowing users to create new digital entries, read existing data, update information, and delete records as needed. These operations are implemented using SPARQL queries and Resource Description Framework (RDF) storage [18][19].

In the Demonstration and Evaluation phase, the researcher conducts simulations and tests related to the system to validate the concept. Testing is performed in two stages: 1) Ontology testing to ensure that each SPARQL query functions correctly; 2) Black-Box testing to evaluate the system's functionality. The Communication phase is the final stage, where the researcher will publish the research findings.

RESULT AND DISCUSSION







The data for this research uses 35 Balinese lontar manuscripts sourced from the Gedong Kirtya Lontar Museum. The primary data source is the collection of Balinese lontar manuscripts, which has been converted into metadata for use as input in the development of the ontology and system implementation. Some of the metadata used can be seen in Table 1

The collected metadata is then used to build the ontology design that represents the semantic structure of the lontar manuscripts. An ontology generally comprises four main components used to build semantic concepts. These main components include classes, object properties, data properties, and instances. The ontology development is carried out with the help of Protege software.

Table 1. Balinese Lontar Manuscript Metadata

Metadata	Data Lontar					
Lontar	1	2	3	4	5	6
Title	Bhasma	Puja Daha	Puja Daha Pasilih	Pitra Puja	Puja Purwaka	Sawa Wedana
Type	Daun Rontar	Daun Rontar	Daun Rontar	Daun Rontar	Daun Rontar	Daun Rontar
Penulis	Pedanda Anyar	Pekak Tjahou	Ida Nyoman Rai	Pedanda Wayan Carik	Pedanda Budha Tusan	Pedanda Budha Tusan
Subject	Mantra	Mantra	Mantra	Mantra	Mantra	Mantra
Klasifikasi	Weda	Weda	Weda	Weda	Weda	Weda

Metadata	Data Lontar					
Lontar	1	2	3	4	5	6
Language	Kawi	Kawi	Kawi	Kawi	Kawi	Kawi
Collation	15	10	41	38	7	11
Year	1962	1929	1962	-	-	1930
Length	50 cm	46 cm	37 cm	38 cm	50 cm	50 cm
Width	3,5 cm	3,5 cm	3,5 cm	3,5 cm	3,5 cm	3,5 cm

Resource						
Place Name	Gedong Kirtya	Gedong Kirtya	Gedong Kirtya	Gedong Kirtya	Gedong Kirtya	Gedong Kirtya
Location	Jalan Veteran No 20, Singaraja	Jalan Veteran No 20, Singaraja	Jalan Veteran No 20, Singaraja	Jalan Veteran No 20, Singaraja	Jalan Veteran No 20, Singaraja	Jalan Veteran No 20, Singaraja
Origin	Belah Batuh, Gianyar	Abiansemal, Badung	Banjar Ulapan, Belah Kiuuh, Gianyar	Denpasar	Banjar Angkan, Klungkung	Banjar Angkan, Klungkung

The implementation of the ontology metadata model has been conducted in the research "The Balinese Lontar Manuscript Metadata Model: An Ontology-Based Approach." The results of this research indicate that using ontology-based methodology for metadata development can provide the necessary information to describe, categorize, and link ontology entities. Figure 2 illustrates the implementation of the ontology design using Protege, while the visual or graphical representation of the lontar manuscript ontology structure is depicted in Figure 3.

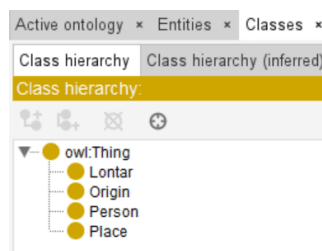


Figure 2. Representation of the lontar manuscript ontology

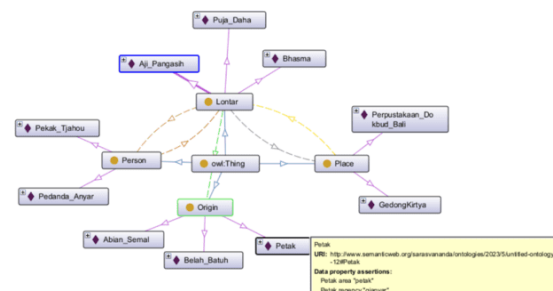


Figure 3. Ontograf

System Implementation

During the system implementation stage, a server capable of handling ontology processing is required. The server used is Apache Jena Fuseki. The ontology files created in Protege are uploaded to the server in OWL (Ontology Web Language) format. The upload process and verification of success or failure on Apache Jena Fuseki can be seen in Figures 4 and 5.

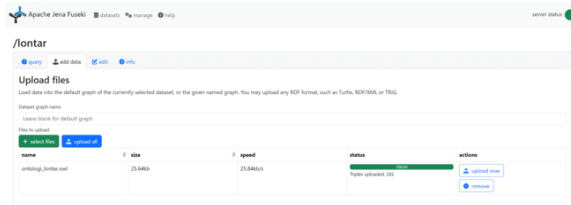


Figure 4. Upload File OWL to Apache Jena Fuseki



Figure 5. Upload result

To connect the server to the source code of the website used for managing SPARQL, the researcher uses the EASYRDF library to handle PHP programming and SPARQL. Below are some explanations of the CRUD source code implementation.

When performing data addition with SPARQL queries, there are several points to consider as follows:

- 1) Defining the *Endpoint*
Ensure correct access to the SPARQL endpoint, such as using the update endpoint for data manipulation and addition http://localhost:3030/pencarian_lontar/update.
- 2) INSERT Query Structure
SPARQL has a specific format for adding data, which uses "INSERT DATA."
- 3) *Namespace dan Prefix*
Use the appropriate prefixes to shorten URIs, such as `lontar:http://www.semanticweb.org/sarasvananda/ontologies/2023/5/untitled-ontology-12#`
- 4) Include All Required Triples
- 5) Ensure that all triples necessary for representing the information are included. Triples consist of a subject, predicate, and object

The implementation of the data addition source code can be seen in Figure 6.

When performing data deletion with SPARQL queries, there are several points to consider as follows:

1. Defining the Endpoint
Ensure correct access to the SPARQL endpoint, such as using the update endpoint for data deletion: http://localhost:3030/pencarian_lontar/update.

2. DELETE Query Structure
SPARQL has a specific format for deleting data, which uses "DELETE."

```

if (isset($_POST['TambahData'])) {
$title = htmlspecialchars($_POST['title']);
$type = htmlspecialchars($_POST['type']);
$subject = htmlspecialchars($_POST['subject']);
$author = htmlspecialchars($_POST['penulis']);
$classification =
htmlspecialchars($_POST['klasifikasi']);
$bahasa = htmlspecialchars($_POST['bahasa']);
$collation =
htmlspecialchars($_POST['collation']);
$tahun =
htmlspecialchars($_POST['tahun_lontar']);
$panjang_lontar=htmlspecialchars($_POST['panjang_lontar']);
$lebar_lontar =
htmlspecialchars($_POST['lebar_lontar']);
$placename =
htmlspecialchars($_POST['nama_tempat']);
$location = htmlspecialchars($_POST['lokasi']);
$area = htmlspecialchars($_POST['area']);
$regency = htmlspecialchars($_POST['regency']);

$resources = upload();
if ($resources === false) {return false;}
$resourcesTriples = '';
if (is_array($resources)) {
foreach ($resources as $resource) {
$resourcesTriples .= "lontar:resource
'$resource';\n";}}
$query = "
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX lontar:
<http://www.semanticweb.org/sarasvananda/ontologies/2023/5/untitled-ontology-12#>
INSERT DATA {
lontar:$title_lontar rdf:type lontar:Lontar ;
lontar:title '$title' ;lontar:type '$type' ;
lontar:subject '$subject' ;
lontar:classification '$classification' ;
lontar:language '$bahasa' ;
lontar:collation '$collation' ;
lontar:year '$tahun' ;
lontar:length $panjang_lontar ;
lontar:width $lebar_lontar ;
$resourcesTriples;lontar:comeFrom
lontar:Origin_$title_lontar;
lontar:createBy lontar:Person $title_lontar ;
lontar:saveIn lontar:Place $title_lontar .
lontar:Origin_$title_lontar rdf:type
lontar:Origin ;lontar:area
'$area';lontar:regency '$regency' .
lontar:Place_$title_lontar rdf:type
lontar:Place ;
lontar:hasSavelontar:$title_lontar
;lontar:placename '$placename' ;lontar:location
'$location' .
lontar:Person_$title_lontar rdf:type
lontar:Person ;
lontar:hasCreate lontar:$title_lontar ;
lontar:author '$author';lontar:address '-';
lontar:cv '- . } ";

$sparql = new
\EasyRdf\Sparql\Client('http://localhost:3030/pencarian_lontar/update');
$result = $sparql->update($query);

```

Figure 6. Source Code INSERT Data

3. Namespace and Prefix
Use appropriate prefixes to shorten URIs, such as `lontar:http://www.semanticweb.org/sarasvananda/ontologies/2023/5/untitled-ontology-12#`.

4. Include All Required Triples

Ensure that all triples necessary for representing the information are included. Triples consist of a subject, predicate, and object.

The implementation of the data modification source code can be seen in Figure 7.

```

if (isset($_POST['EditData'])) {
$title = htmlspecialchars($_POST['title']);
$type = htmlspecialchars($_POST['type']);
$subject = htmlspecialchars($_POST['subject']);
$author = htmlspecialchars($_POST['penulis']);
$classification =
htmlspecialchars($_POST['klasifikasi']);
$bahasa = htmlspecialchars($_POST['bahasa']);
$collation =
htmlspecialchars($_POST['collation']);
$tahun =
htmlspecialchars($_POST['tahun_lontar']);
$panjang_lontar=htmlspecialchars($_POST['panjang
g_lontar']);
$lebar_lontar =
htmlspecialchars($_POST['lebar_lontar']);
$placename =
htmlspecialchars($_POST['nama_tempat']);
$location = htmlspecialchars($_POST['lokasi']);
$area = htmlspecialchars($_POST['area']);
$regency = htmlspecialchars($_POST['regency']);
});
$gambarLama=
htmlspecialchars($_POST['gambar_lama']);
$id = $_POST['id_title'];
$oldTitle_lontar= str_replace(' ', '_', $id);
$new_title = str_replace(' ', '_', $title);

// cek apakah user pilih gambar baru atau tidak?
if ($_FILES['upload_image']['error'] === 4) {
$resources = explode(',', $gambarLama);
} else {$resources = upload();}
$resourceTriplesOld = '';
$resourceTriplesNew = '';
foreach ($resources as $resource) {
$resourceTriplesOld .= "lontar:resource
?oldResource ;\n";
$resourceTriplesNew .= "lontar:resource
'$resource' ;\n";}
$query = "
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-
syntax-ns#>
PREFIX lontar:
<http://www.semanticweb.org/sarasvananda/ontolo
gies/2023/5/untitled-ontology-12#>

DELETE WHERE {
lontar:$oldTitle_lontar rdf:type lontar:Lontar;
lontar:title ?oldTitle ;lontar:type ?oldType ;
lontar:subject ?oldSubject ;
lontar:classification ?oldClassification ;
lontar:language ?oldLanguage ;
lontar:collation ?oldCollation; lontar:year
?oldYear ;lontar:length ?oldLength ;
lontar:width ?oldWidth;$resourceTriplesOld ;

```

```

lontar:width $lebar_lontar ;
$resourceTriplesNew ;
lontar:comeFrom lontar:Origin_$new_title ;
lontar:createBy lontar:Person_$new_title ;
lontar:saveIn lontar:Place_$new_title .
lontar:Origin_$new_title rdf:type lontar:Origin
; lontar:area '$area' ;lontar:regency
'$regency' .
lontar:Place_$new_title rdf:type lontar:Place ;
lontar:hasSave lontar:$new_title ;
lontar:placename '$placename' ;
lontar:location '$location' .
lontar:Person_$new_title rdf:type lontar:Person
; lontar:hasCreate lontar:$new_title ;
lontar:author '$author' ;lontar:address '-' ;
lontar:cv '-' .}

```

```

$sparql = new
\EasyRdf\Sparql\Client('http://localhost:3030/p
encarian_lontar/update');
$result = $sparql->update($query);

```

Figure 7. The implementation of the data modification

When performing data deletion with SPARQL queries, there are several points to consider as follows:

1. Defining the Endpoint
Ensure correct access to the SPARQL endpoint, such as using the update endpoint for data deletion:
http://localhost:3030/pencarian_lontar/updates.
2. DELETE Query Structure
SPARQL uses a specific format for deleting data, which is "DELETE."
3. Namespace and Prefix
Use appropriate prefixes to shorten URIs, such as [lontar:http://www.semanticweb.org/sarasvananda/ontologies/2023/5/untitled-ontology-12#](http://www.semanticweb.org/sarasvananda/ontologies/2023/5/untitled-ontology-12#).
4. Include All Required Triples
Ensure that all triples necessary for representing the information are included. Triples consist of a subject, predicate, and object.

The implementation of the data deletion source code can be seen in Figure 8.

```

if (isset($_POST['HapusData'])){ $id =
$_POST['id_title'];
$query = "
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-
syntax-ns#>
PREFIX                                lontar:
<http://www.semanticweb.org/sarasvananda/ontolo-
gies/2023/5/untitled-ontology-12#>
DELETE WHERE {
?lontar lontar:title '$id';
  lontar:type ?type;
  lontar:subject ?subject;
  lontar:classification ?classification;
  lontar:language ?language;
  lontar:collation ?collation;
  lontar:year ?year;
  lontar:length ?length;
  lontar:width ?width;
  lontar:resource ?resource;
  lontar:createBy ?person;
  lontar:comeFrom ?origin;
  lontar:saveIn ?place.
?person lontar:author ?author.
?origin lontar:area ?area;
  lontar:regency ?regency.
?place lontar:placename ?placename;
  lontar:location ?location;
  lontar:hasSave ?lontar.}";
// Membuat objek client SPARQL
  $sparql = new
\EasyRdf\Sparql\Client('http://localhost:3030/p
encarian_lontar/update');
// Melakukan permintaan update dengan kueri
yang telah disiapkan
  $result = $sparql->update($query);

```

Figure 8. Source Code Delete Data

When performing data retrieval with SPARQL queries, there are several points to consider as follows:

1. Defining the Endpoint
Ensure correct access to the SPARQL endpoint, such as using the query endpoint for data retrieval: http://localhost:3030/pencarian_lontar/query.
2. SELECT Query Structure
SPARQL uses a specific format for retrieving data, which is "SELECT."
3. Namespace and Prefix
Use appropriate prefixes to shorten URIs, such as `lontar:http://www.semanticweb.org/sarasvananda/ontologies/2023/5/untitled-ontology-12#`.
4. Include All Required Triples
Ensure that all triples necessary for representing the information are included. Triples consist of a subject, predicate, and object.

The implementation of the source code for retrieving all data can be seen in Figure 9.

```

$sparql = new
\EasyRdf\Sparql\Client('http://localhost:3030/p
encarian_lontar/query');
$query = "
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-
syntax-ns#>
PREFIX                                lontar:
<http://www.semanticweb.org/sarasvananda/ontolo-
gies/2023/5/untitled-ontology-12#>

SELECT ?title ?type ?subject ?classification
?language ?collation ?year ?length ?width
?author ?area ?regency ?placename ?location
(GROUP_CONCAT(?resource; SEPARATOR=',') AS
?resources)
WHERE {
?lontar lontar:title ?title;
  lontar:type ?type;
  lontar:subject ?subject;
  lontar:classification ?classification;
  lontar:language ?language;
  lontar:collation ?collation;
  lontar:year ?year;
  lontar:length ?length;
  lontar:width ?width;
  lontar:resource ?resource;
  lontar:createBy ?person;
  lontar:comeFrom ?origin;
  lontar:saveIn ?place.
?person lontar:author ?author.
?origin lontar:area ?area;
  lontar:regency ?regency.
?place lontar:placename ?placename;
  lontar:location ?location;
  lontar:hasSave ?lontar.
}
GROUP BY ?title ?type ?subject ?classification
?language ?collation ?year ?length ?width
?author ?area ?regency ?placename ?location
ORDER BY ?title";

$result = $sparql->query($query);

```

Figure 9. Source Code View Data

User Interface Implementation

In the implementation of the user interface for the Semantic Approach for Digital Restoration of Balinese Lontar Manuscripts, several technologies are utilized for developing the Front-End and Back-End, including HTML, Tailwind CSS, JavaScript, and PHP. This interface provides key features such as searching for lontar manuscripts using ontology technology, as well as adding and updating manuscript data.

Users can easily view the details of each lontar manuscript and manage the associated metadata through interactive forms. Additionally, integration with the SPARQL endpoint allows semantic queries to be executed directly from the user interface, facilitating user searches and data manipulation. With a user-friendly design, this system is expected to effectively support the conservation and digital restoration of Balinese lontar manuscripts. The system can be accessed at www.lontarbali.id.

1) Home

On the home page, there are several features for viewing profile data, collections of identified lontar manuscripts, and the number of lontar manuscripts distributed

across various regions. The image of the home page can be seen in Figure 10.

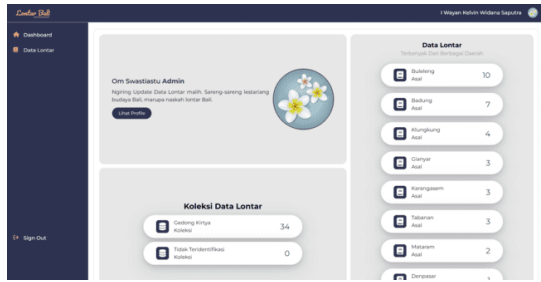


Figure 10. Dashboard

2) Lontar Table Page

The lontar data table page is a system interface that displays the entire content of lontar data. This page includes several features such as adding data, viewing data, modifying data, deleting data, and a data search menu. The image of the data table page can be seen in Figure 11.



Figure 11. Table Lontar Page

3) Add Data Pop-up Form

The add data pop-up form is the interface used to save lontar data into the database. This form allows the addition of information such as title, type, subject, classification, language, number of pages, year, size, storage place and location, as well as the origin of the lontar. The image of this pop-up form can be seen in Figure 12, and the evidence of data addition is shown in Figure 13.

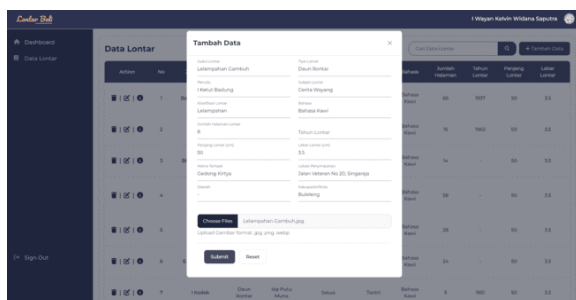


Figure 12. Lontar Data Add Pop-up Form

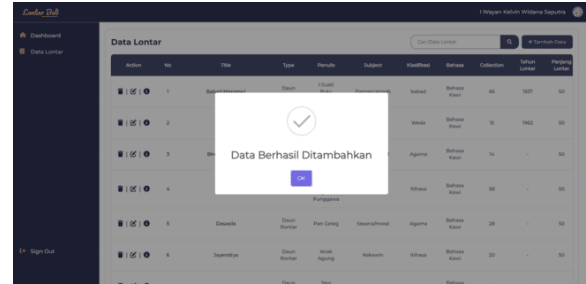


Figure 13. Data Successfully Added

4) Lontar Data Edit Pop-up Form

The lontar data edit pop-up form is the interface used to modify lontar data. This interface allows changes to information such as title, type, subject, classification, language, number of pages, year, size, storage place and location, origin, district/city, and lontar image. The image of this pop-up form can be seen in Figure 14, and the evidence of data modification is shown in Figure 15.

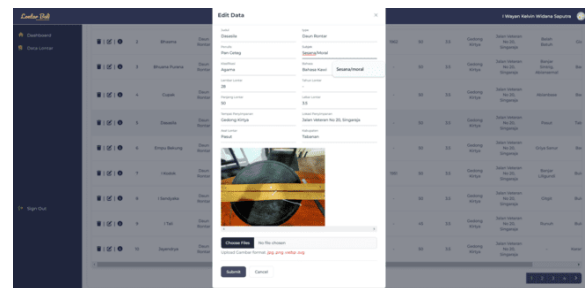


Figure 14. Lontar Data Edit Pop-up Form

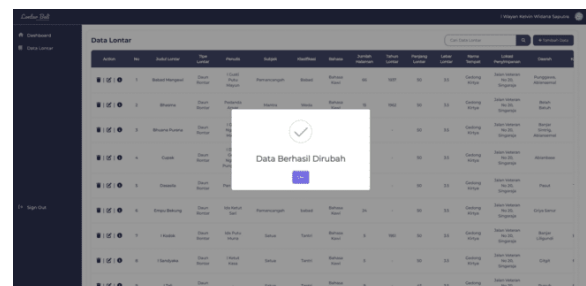


Figure 15. Proof of Successful Data Modification

5) Delete Data Lontar

Deleting lontar data is the user interface display of the system when wanting to remove selected lontar data. When an admin attempts to delete lontar data, a pop-up appears to confirm whether they are sure about deleting the data. The image of the deletion validation pop-up can be seen in Figure 16, and the proof of successful data deletion is shown in Figure 17.

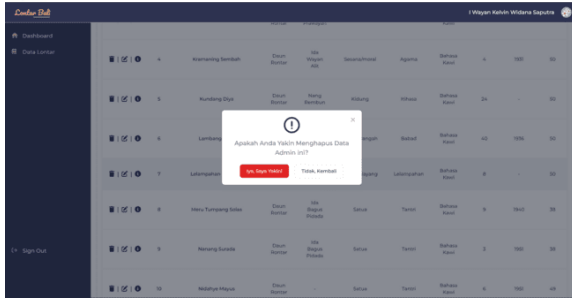


Figure 16. Lontar Data Deletion Validation Pop-up

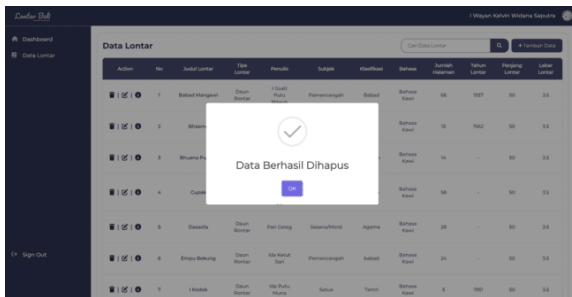


Figure 17. Lontar Data Successfully Deleted

TESTING

During the testing phase, two stages are conducted: ontology testing and black-box testing. In ontology testing, questions are posed regarding the aspects of adding, deleting, and modifying lontar data within the constructed ontology model.

Table 2. list of questions used to test the created lontar manuscript ontology

No	Questions
1	Is it possible to add lontar data using the constructed ontology?
2	Is it possible to delete the lontar data titled "Bhasma"?
3	Is it possible to change the classification of lontar data from Weda to Tantri?
4	Is it possible to display all stored lontar data?

Based on the questions formulated above, the ontology model of Balinese lontar manuscripts will be tested using SPARQL.

- Question 1: Is it possible to add lontar data using the constructed ontology?

```

PREFIX          lontar:
<http://www.semanticweb.org/sarasvananda/ontologies/2023/5/untitled-ontology-12#>
PREFIX          rdf:
<http://www.w3.org/1999/02/22-rdf-syntax-ns#>
INSERT DATA {
  lontar:Bhasma_lontar      rdf:type
  lontar:Lontar ;
  lontar:title 'Bhasma' ;
  lontar:type 'Daun Rontar' ;

```

```

lontar:subject 'Mantra' ;
lontar:classification 'Weda' ;
lontar:language 'Bahasa Kawi' ;
lontar:collation '15' ;
lontar:year '1962' ;
lontar:length '50' ;lontar:width '3.5' ;
lontar:resource 'Gambar1.jpg';
lontar:comeFrom lontar:Origin_Bhasma;
lontar:createBy lontar:Person_Bhasma ;
lontar:saveIn lontar:Place_Bhasma .
lontar:Origin_Bhasma      rdf:type
lontar:Origin ;
lontar:area 'Belah Batuh';
lontar:regency 'Gianyar' .
lontar:Place_Bhasma      rdf:type
lontar:Place ;
lontar:hasSave lontar:Bhasma_lontar ;
lontar:placename 'Gedong Kirtya' ;
lontar:location 'Jalan Veteran No 20,
Singaraja' .
lontar:Person_Bhasma      rdf:type
lontar:Person ;
lontar:hasCreate lontar:Bhasma_lontar;
lontar:author 'Pedanda Anyar';
lontar:address '-';
lontar:cv '- ' .}

```

Table Response Response in 0.119 seconds
Could not render results with the Table plugin, the results currently

1	Update succeeded
2	

Figure 18. Results of Testing Question 1

- Question 2: Is it possible to delete the lontar data titled "Bhasma"?

```

PREFIX lontar:
<http://www.semanticweb.org/sarasvananda/ontologies/2023/5/untitled-ontology-12#>
PREFIX rdf:
<http://www.w3.org/1999/02/22-rdf-syntax-ns#>
DELETE WHERE {
  ?lontar lontar:title 'Bhasma';
  lontar:type ?type;
  lontar:subject ?subject;
  lontar:classification
?classification;
  lontar:language ?language;
  lontar:collation ?collation;
  lontar:year ?year; lontar:length
?length;
  lontar:width ?width;
  lontar:resource ?resource;
  lontar:createBy ?person;
  lontar:comeFrom ?origin;
  lontar:saveIn ?place.
?person lontar:author ?author.
?origin lontar:area ?area;
  lontar:regency ?regency.
?place lontar:placename ?placename;
  lontar:location ?location;
  lontar:hasSave ?lontar.
}

```

ID	author	type	subject	classification	language	collation	year	length	width	resource	area	regency	placename	location
1	Pada Duta	Daun R.	Mantra	Weda	Bahasa Ka.	15	1962	50	3.5		Belah Batuh	Gianyar	Gedong Kirtya	Jalan Veteran No. 20, Singaraja
2	Pada Duta-Pada	Daun R.	Mantra	Weda	Bahasa Ka.	15	1962	50	3.5		Belah Batuh	Gianyar	Gedong Kirtya	Jalan Veteran No. 20, Singaraja
3	Pada Duta	Daun R.	Mantra	Weda	Bahasa Ka.	15	1962	50	3.5		Belah Batuh	Gianyar	Gedong Kirtya	Jalan Veteran No. 20, Singaraja
4	Pada Duta	Daun R.	Mantra	Weda	Bahasa Ka.	15	1962	50	3.5		Belah Batuh	Gianyar	Gedong Kirtya	Jalan Veteran No. 20, Singaraja
5	Pada Duta	Daun R.	Mantra	Weda	Bahasa Ka.	15	1962	50	3.5		Belah Batuh	Gianyar	Gedong Kirtya	Jalan Veteran No. 20, Singaraja
6	Pada Duta	Daun R.	Mantra	Weda	Bahasa Ka.	15	1962	50	3.5		Belah Batuh	Gianyar	Gedong Kirtya	Jalan Veteran No. 20, Singaraja
7	Pada Duta	Daun R.	Mantra	Weda	Bahasa Ka.	15	1962	50	3.5		Belah Batuh	Gianyar	Gedong Kirtya	Jalan Veteran No. 20, Singaraja
8	Pada Duta	Daun R.	Mantra	Weda	Bahasa Ka.	15	1962	50	3.5		Belah Batuh	Gianyar	Gedong Kirtya	Jalan Veteran No. 20, Singaraja
9	Pada Duta	Daun R.	Mantra	Weda	Bahasa Ka.	15	1962	50	3.5		Belah Batuh	Gianyar	Gedong Kirtya	Jalan Veteran No. 20, Singaraja
10	Pada Duta	Daun R.	Mantra	Weda	Bahasa Ka.	15	1962	50	3.5		Belah Batuh	Gianyar	Gedong Kirtya	Jalan Veteran No. 20, Singaraja
11	Pada Duta	Daun R.	Mantra	Weda	Bahasa Ka.	15	1962	50	3.5		Belah Batuh	Gianyar	Gedong Kirtya	Jalan Veteran No. 20, Singaraja

Figure 19. Results of Testing Question 2

3. Question 3: Is it possible to change the classification of lontar data from Weda to Tantri?

```
DELETE WHERE {
  lontar:Jayendrya rdf:type
  lontar:Lontar ; lontar:title
  ?oldTitle; lontar:type ?oldType;
  lontar:subject ?oldSubject ;
  lontar:classification
  ?oldClassification; lontar:language
  ?oldLanguage; lontar:collation
  ?oldCollation; lontar:year ?oldYear ;
  lontar:length ?oldLength;
  lontar:width ?oldWidth ;
  lontar:resource ?oldResource;
  lontar:comeFrom ?oldOrigin;
  lontar:createBy ?oldCreator ;
  lontar:saveIn ?oldPlace .
  ?oldOrigin rdf:type lontar:Origin;
  lontar:area ?oldArea ;lontar:regency
  ?oldRegency .
  ?oldPlace rdf:type lontar:Place ;
  lontar:hasSave ?oldLontar
  ;lontar:placename ?oldPlacename ;
  lontar:location ?oldLocation .
  ?oldCreator rdf:type lontar:Person ;
  lontar:hasCreate ?oldLontar ;
  lontar:author ?oldAuthor ;
  lontar:address ?oldAddress ;lontar:cv
  ?oldCV .}

INSERT {
  lontar:Jayendrya rdf:type
  lontar:Lontar;
  lontar:title 'Jayendrya' ;
  lontar:type 'Daun Lontar';
  lontar:subject 'Kidung';
  lontar:classification 'Tantri' ;
  lontar:language 'Bahasa Kawi' ;
  lontar:collation 20;
  lontar:year '-' ;
  lontar:length 50 ;
  lontar:width 3.5 ;
  lontar:resource 'img_jaya.jpg' ;
  lontar:comeFrom
  lontar:Origin Jayendrya ;
  lontar:createBy ;
  lontar:Person_Jayendrya ;
  lontar:saveIn
  lontar:Place_Jayendrya.
  lontar:Origin_Jayendrya rdf:type
  lontar:Origin ;
  lontar:area '-' ;
  lontar:regency 'Karangasem' .
  lontar:Place_Jayendrya rdf:type
  lontar:Place ;
  lontar:hasSave lontar:Jayendrya ;
  lontar:placename 'Gedong Kirtya' ;
  lontar:location 'Jalan Veteran No 20,
  Singaraja' .
  lontar:Person_Jayendrya rdf:type
  lontar:Person ;
  lontar:hasCreate lontar:Jayendrya ;
  lontar:author 'Anak Agung' ;
  lontar:address '-' ;lontar:cv '-' .}
```

Table Response Response in 0.142 seconds

Could not render results with the Table plugin, the results

1	Update succeeded
2	

Figure 20. Results of Testing Question 3

4. Question 4: Is it possible to display all stored lontar data?

```
PREFIX rdf:
<http://www.w3.org/1999/02/22-rdf-
syntax-ns#>
PREFIX lontar:
<http://www.semanticweb.org/sarasvananda
/ontologies/2023/5/untitled-ontology-
12#>
SELECT ?title ?type ?subject
?classification ?language ?collation
?year ?length ?width ?author ?area
?regency ?placename ?location
(GROUP_CONCAT(?resource;
SEPARATOR=',')
AS ?resources)
WHERE {
  ?lontar lontar:title ?title;
  lontar:type ?type;
  lontar:subject ?subject;
  lontar:classification
  ?classification;
  lontar:language ?language;
  lontar:collation ?collation;
  lontar:year ?year;
  lontar:length ?length;
  lontar:width ?width;
  lontar:resource ?resource;
  lontar:createBy ?person;
  lontar:comeFrom ?origin;
  lontar:saveIn ?place.
  ?person lontar:author ?author.
  ?origin lontar:area ?area;
  ?place lontar:regency ?regency.
  ?place lontar:placename ?placename;
  lontar:location ?location;
  lontar:hasSave ?lontar.
}
GROUP BY ?title ?type ?subject
?classification ?language ?collation
?year ?length ?width ?author ?area
?regency ?placename ?location
ORDER BY ?title
```




Figure 21. Results of Testing Question 4

Based on the results of ontology knowledge testing, it can be concluded that the processes of adding, deleting, and modifying lontar data are functioning well. The ontology successfully accommodates new data, deletes unnecessary information, and updates data accurately without causing conflicts or inconsistencies in the data structure.

Next, black-box testing is conducted to evaluate the functionality of the system from the end-user's perspective [20]. Below are the scenarios for Black-Box Testing of the Semantic Approach For Digital Restoration Of Balinese Lontar Manuscripts system.

Table 3. Black-Box Testing Scenarios

No	Scenarios	Expected Results
1	The admin can access the website's homepage.	The system should display information related to the lontar collection data and show the most numerous lontar data from various regions in Bali.
2	The admin clicks the "Add Lontar Data" button and then clicks the "Save Data" button.	The system should display a pop-up form for adding lontar data and should be able to add lontar data successfully.
3	Admin clicks the edit icon and the save button.	The system displays a pop-up for editing lontar data and successfully saves the updated lontar data to the database.
4	The admin clicks the "Delete Data" button and then clicks the "Validate" button.	The system should display a confirmation pop-up asking if the admin is sure they want to delete the data and then show a notification pop-up indicating that the data has been successfully deleted.
5	The admin clicks the search icon button.	The system should display the lontar information that the user is looking for.
6	The admin can access the lontar detail page by clicking the information icon button.	The system should display detailed information about the lontar, including its title, type, author, subject, classification, language, number of pages, year of the lontar, length, width, image, storage location, place of storage, origin/region, and district or city.

Table 4. Results of Black-Box Testing

No	Expected Results	Results
1	The system should display information related to the lontar collection data and show the most numerous lontar data from various regions in Bali.	Valid
2	The system should display a pop-up form for adding lontar data and should be able to add lontar data successfully.	Valid
3	The system displays a pop-up for editing lontar data and successfully saves the updated lontar data to the database.	Valid
4	The system should display a confirmation pop-up asking if the admin is sure they want to delete the data and then show a notification pop-up indicating that the data has been successfully deleted.	Valid
5	The system should display the lontar information that the user is looking for.	Valid

6	The system should display detailed information about the lontar, including its title, type, author, subject, classification, language, number of pages, year of the lontar, length, width, image, storage location, place of storage, origin/region, and district or city.	Valid
---	--	-------

Based on the results of the black-box testing, it is evident that the system has functioned effectively and met the expectations of the testers. Therefore, the Semantic Approach for Digital Restoration of Balinese Lontar Manuscripts system operates well and is ready for use.

CONCLUSION

Based on the results and discussion, the author can draw the following conclusions: The research on the semantic approach for the digital restoration of Balinese lontar manuscripts has successfully demonstrated that ontology-based methods can effectively manage and restore these valuable manuscripts. By utilizing CRUD operations within the ontology framework, the system has proven its ability to accommodate new data, ensure accurate information updates, and maintain the integrity of relationships between various entities.

The results of both ontology knowledge testing and black-box testing indicate that the processes for adding, deleting, and modifying lontar data function smoothly without causing conflicts or inconsistencies. The Semantic Approach For Digital Restoration Of Balinese Lontar Manuscripts system operates as expected and is ready for use.

ACKNOWLEDGMENT

The author expresses gratitude to the Ministry of Education, Research, and Technology of Indonesia for the grant received to conduct this research as part of the Beginner Lecturer Research Scheme.

REFERENCES

- [1] Ketut Gura Arta Laras, "Digitisasi Lontar Museum Naskah Lontar Desa Adat Dukuh Penaban, Kecamatan Karangasem, Kabupaten Karangasem, Bali," *Widya Aksara J. Agama Hindu*, vol. 26, no. 1, pp. 1–12, 2021, doi: 10.54714/widyaaksara.v26i1.142.
- [2] N. P. M. Erlina Putri, I. G. I. Sudipa, I. K. A. G. Wiguna, I. B. G. Sarasvananda, and I. W. Sunarya, "Decision Making Model for Temple Revitalization in Bali Using Fuzzy-SMARTER Combination Method," *Sinkron*, vol. 9, no. 1, pp. 61–74, 2024,

- doi: 10.33395/sinkron.v9i1.13177.
- [3] I. Siliutina, O. Tytar, M. Barbash, N. Petrenko, and L. Yepyk, "Cultural preservation and digital heritage: challenges and opportunities," *Rev. Amaz. Investig.*, vol. 14, no. 75, pp. 262–273, 2024, doi: 10.34069/ai/2024.75.03.22.
- [4] P. W. Aditama, N. K. D. Juniantari, I. M. S. Sandhiyasa, I. B. G. Sarasvananda, and I. G. I. Sudipa, "Digitalisasi Warisan Benda Bersejarah Pada Kawasan Pura Pucak Penulisan Menggunakan Metode Waterfall," *J. Inf. Syst. Res.*, vol. 4, no. 4, pp. 1253–1261, 2023, doi: 10.47065/josh.v4i4.3733.
- [5] E. D. Prasetya, B. Priyambadha, and F. A. Bachtiar, "Pengembangan Sistem Aplikasi Pencarian Dosen Pembimbing Skripsi dengan Teknologi Web Semantik (Studi Kasus: Fakultas Ilmu Komputer Universitas Brawijaya)," *J. Pengemb. Teknol. Inf. dan Ilmu Komput. e-ISSN*, vol. 2548, no. 9, p. 964X, 2019.
- [6] C. Pramatha, "PENGEMBANGAN ONTOLOGI TUJUAN WISATA BALI DENGAN PENDEKATAN KULKUL KNOWLEDGE FRAMEWORK," *SINTECH (Science Inf. Technol. J.)*, vol. 3, no. 2, pp. 77–89, Oct. 2020, doi: 10.31598/SINTECHJOURNAL.V3I2.592.
- [7] I. Bagus, G. Sarasvananda, P. Gede, and S. Cipta Nugraha, "The Balinese Lontar Manuscript Metadata Model: An Ontology-Based Approach," *J. Multidisiplin Madani*, vol. 3, no. 9, pp. 1964–1971, Sep. 2023, doi: 10.55927/MUDIMA.V3I9.5850.
- [8] M. Wardana and C. R. A. Pramatha, "Development of Semantic Ontology Modeling in Knowledge Representation of Balinese Gamelan Instruments," *JELIKU (Jurnal Elektron. Ilmu Komput. Udayana)*, vol. 8, no. 2, p. 145, Jan. 2020, doi: 10.24843/JLK.2019.V08.I02.P06.
- [9] A. Goldstein, L. Fink, and G. Ravid, "A framework for evaluating agricultural ontologies," *Sustain.*, vol. 13, no. 11, pp. 1–12, 2021, doi: 10.3390/su13116387.
- [10] W. M. W. Isa *et al.*, "An ontological approach for creating a brassware craft knowledge base," *IEEE Access*, vol. 8, pp. 163434–163446, 2020, doi: 10.1109/ACCESS.2020.3022795.
- [11] F. Neuhaus and J. Hastings, "Ontology development is consensus creation, not (merely) representation," *Appl. Ontol.*, vol. 17, no. 4, pp. 495–513, Jan. 2022, doi: 10.3233/AO-220273.
- [12] T. Hagedorn, M. Bone, B. Kruse, I. Grosse, and M. Blackburn, "Knowledge Representation with Ontologies and Semantic Web Technologies to Promote Augmented and Artificial Intelligence in Systems Engineering," *INSIGHT*, vol. 23, no. 1, pp. 15–20, Mar. 2020, doi: 10.1002/INST.12279.
- [13] S. F. Pileggi and S. A. Lamia, "Climate Change TimeLine: An Ontology to Tell the Story so Far," *IEEE Access*, vol. 8, pp. 65294–65312, 2020, doi: 10.1109/ACCESS.2020.2985112.
- [14] A. Yeboah-Ofori, U. M. Ismail, T. Swidurski, and F. Opoku-Boateng, "Cyberattack Ontology: A Knowledge Representation for Cyber Supply Chain Security," *Proc. - 2021 Int. Conf. Comput. Comput. Model. Appl. ICCMA 2021*, pp. 65–70, 2021, doi: 10.1109/ICCMA53594.2021.00019.
- [15] D. GENG and Y. WEN, "Research on the Development Method of the Semantic Web Application Based on AllegroGraph," *DEStech Trans. Comput. Sci. Eng.*, vol. 0, no. cisnrc, Dec. 2019, doi: 10.12783/DTCSE/CISNRC2019/33318.
- [16] S. Li, H. Luo, G. Zhao, M. Tang, and X. Liu, "bi-directional Bayesian probabilistic model based hybrid grained semantic matchmaking for Web service discovery," *World Wide Web*, vol. 25, no. 2, pp. 445–470, Mar. 2022, doi: 10.1007/S11280-022-01004-7/FIGURES/10.
- [17] A. M. Rinaldi and C. Russo, "Using a multimedia semantic graph for web document visualization and summarization," *Multimed. Tools Appl.*, vol. 80, no. 3, pp. 3885–3925, Jan. 2021, doi: 10.1007/S11042-020-09761-1/TABLES/12.
- [18] M. Halim, A. Tahiri, Y. El Ghzizal, N. Adadi, and D. Chenouni, "Proposal for an e-learning system model based on the invocation and semantic discovery of web services," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 35, no. 1, pp. 631–641, Jul. 2024, doi: 10.11591/ijeecs.v35.i1.pp631-641.
- [19] I. Bagus, G. Sarasvananda, R. Wardoyo, and A. K. Sari, "The K-Means Clustering Algorithm With Semantic Similarity To Estimate The Cost of Hospitalization," *IJCCS (Indonesian J. Comput. Cybern. Syst.)*, vol. 13, no. 4, pp. 313–322, Oct. 2019, doi: 10.22146/IJCCS.45093.
- [20] B. G. Sarasvananda and I. K. A. G. I. S. Wiguna, "Pendekatan Metode Extreme Programming untuk Pengembangan



Sistem Informasi Manajemen Surat
Menyurat pada LPIK STIKI," *J. Inform.
Univ. Pamulang*, vol. 6, no. 2, pp. 258–
267, 2021, [Online]. Available:

<http://openjournal.unpam.ac.id/index.php/informatika258>