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by dessyhariyanti@gmail.com 1

Submission date: 27-Sep-2024 10:03AM (UTC-0700)
Submission ID: 2467426565
File name: JOIV_Template_2023_dessy_temp.docx (689.14K)
Word count: 5543
Character count: 32936

Ontology Modelling for Subak Knowledge Management System

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***Abstract*— *Subak* is an irrigation and agricultural management organization based on Balinese customs that has cultural heritage knowledge, including not only material artifacts but also tacit knowledge contained in practices, traditions, and expertise, as well as explicit knowledge in the form of stories, literature, and official records. This study found that there has been no research on the development of ontology-based *Subak* knowledge, especially in the context of cultural preservation. This study aims to build a *Subak* ontology knowledge model for digitalization of cultural preservation in the form of a Knowledge Management System. The development of the ontology model goes through three main stages: requirement Analysis, namely data collecting through field observations, in-depth interviews, and document analysis. Ontology Development defines hierarchical classes, object and data properties, and individual entities. The ontology model is implemented using protégé. The ontology builds Ontograf and produces OWL (Ontology Web Language). Then, ontology Assessments are the stage of implementing the evaluation and testing of the ontology produced. Validation is carried out with OntoQA (Ontology Quality Analysis) and expert comments. The evaluation results show a Relationship Richness (RR) value of 0.8, an Inheritance Richness (IR) value of 0.78, and an Attribute Richness (AR) value of 3.89. It can be concluded that the ontology produced is quite rich and has representative knowledge. From the expert comments stated that the ontology model created is worthy of being used to represent *Subak* knowledge as a form of cultural preservation. The resulting *Subak* ontology can be a reference as a knowledge base for the development of other ontologies in the domains of agricultural management, social organization, and cultural preservation..**

***Keywords*— Ontology, Cultural Heritage, Knowledge representation, Knowledge based, Knowledge Management System**

Manuscript received 15 Oct. 2020; revised 29 Jan. 2021; accepted 2 Feb. 2021. Date of publication 17 Feb. 2021.

I. Introduction

Cultural heritage is increasingly fading [1] due to the influence of globalization and social change, which shift traditional values and a lack of attention to maintaining and disseminating knowledge. Cultural heritage knowledge [2] includes not only material artifacts but also tacit knowledge contained in practices, traditions, and skills passed down from generation to generation, as well as explicit knowledge documented in the form of stories, literature, and official records.

UNESCO calls for joint action in documenting, preserving, and protecting ancestral cultural practices and knowledge that are increasingly being degraded today, one of which is through digitization [3]. UNESCO emphasizes the importance of digitization efforts based on sustainability principles, community participation, access to information, and a comprehensive knowledge management system [4] mainly provided for future generations. Knowledge Management System (KMS) is a system that provides a structured platform [5] that allows an organization to collect, store, organize, and share knowledge efficiently.

The development of KMS requires a knowledge representation model, where the implementation of ontology is one solution to capture knowledge [6] that has yet to be documented. Ontology, as a formal model of knowledge, provides a framework for defining concepts, relations, properties, and rules in the knowledge domain[7]. This enables consistency of organization and interoperability as well as computer understanding of the context and meaning

[8] of knowledge in an effort to use it more effectively for various needs.

Subak is an organization that manages a traditional irrigation system in Bali based on the principles of Tri Hita Karana [9], which has been recognized by UNESCO [10] as a world cultural heritage covering social, cultural, ecological values and agricultural practices related to it. *Subak* has its uniqueness in the creation of collaborative knowledge [11]. Traditional methods in transferring intangible heritage knowledge [12] are often carried out through personal and verbal exchange of information. The challenges of modernization and urbanization [9] trigger a decrease in the younger generation's involvement in direct *Subak* practices, so knowledge is vulnerable to erosion over time. Meanwhile, in supporting the organization's existence, this knowledge needs to be captured and shared with the next generation through technological innovation[13], one of which is through a knowledge management system.

Based on the initial observations, it was found that *Subak* knowledge, tacit and explicit, needs to be managed better and that the media should display it comprehensively. So, it is essential to create an ontology model to represent the knowledge base for developing the *Subak* knowledge management system and support efforts to digitize cultural preservation. In addition, the resulting *Subak* Ontology can later be a reference for developing other ontologies in agricultural management, social organizations, and cultural preservation. Ontology research and development have been widely conducted based on various research methodologies in various cultural preservation domains. Most cultural preservation ontologies are formed from scratch [14]. This causes the research methodology to be more adjusted to the characteristics of data collection challenges and the scope of the knowledge domain [15],[16]. Previous research conducted a literature study[17] in formulating the *Subak* ontology development research methodology as a stage of this research.

In the conceptual data stage, Ontology modeling [18] is needed to represent knowledge. CIDOC-CRM [19] is an ontology modeling developed to align the domains of libraries, museums, archives, and cultural data collections. To date, CIDOC-CRM has determined 99 classes and 198 properties. In this study, CIDOC-CRM is only used as a modeling reference[20], and many adjustments are made [21],[22] considering the complexity and characteristics of specific *Subak* domains are very different from the framework offered.

Ontology assessment involves external validation[23], including Competency Questions-based[24] and Expert confirmatory[7]. Internal consistency uses ontology metrics [1][24][25][26]. Given the ever-growing knowledge, knowledge sufficiency is overcome by continuous and structured knowledge enrichment [17].

Many researches have been conducted about KMS in heritage culture[4]. No research development of ontology-based KMS *Subak* has ever been conducted through the literature review[14]. This study proposes developing ontology-based knowledge model for the digitalization of *Subak* cultural heritage preservation. So, the main problem formulation of this study is how to create ontology-based knowledge model that can represent *Subak* knowledge in the preservation of cultural heritage knowledge. The results of this study are in the form of ontology-based knowledge model for the representation of the *Subak* knowledge management system.

II. Methodology

Ontology will show how the adequacy of knowledge is presented. Ontology development activities are one of the fundamental steps in supporting the knowledge management process [27]. Therefore, it is necessary to pay attention to how to design ontology in KMS. The adoption of ontology in KMS is based on the KMS Life Cycle approach which consists of seven stages of development. Based on the seven steps of the KMS Life Cycle, ontology development will be at the Knowledge capture stage[28], as shown in Fig 1. In KMS, the Knowledge Capture stage consists of Knowledge Acquisition, Knowledge Creation, and Knowledge Evaluation, which are accordance with the framework in this study.

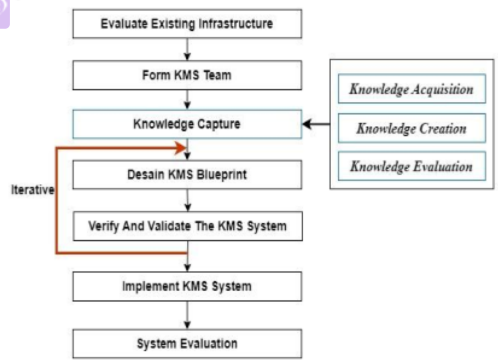

Fig. 1 KMS Life Cycle

The research methodology of this study references CIDOC-CRM[19], with some adjustments made according to the knowledge domain being built. As described in Fig. 2, it consists of four main stages[17]. Ontology development is an iterative process[29].

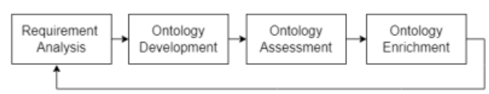

Fig 2 Research Framework

A. *Requirement Analysis*

Building a knowledge base begins with exploratory research, with the aim of determining the facts that form *Subak* knowledge.

1) *Objective Formulation:* formulating general and specific objectives in detail for creating ontology. This objective formulation will form the basis for compiling a list of CQs, which are questions designed to identify the knowledge needed to achieve the purpose of creation[1]. By formulating objectives first, ontology developers can ensure that the CQs compiled will be relevant and focused on achieving the goals that have been set. This stage produces a list of CQs.

2) *Domain Acquisition:* is the stage of acquiring *Subak* knowledge. Because the *Subak* ontology has never been created, the acquisition is carried out from the beginning (scratch)[14]. The data sources that will be used in the study are primary and secondary data. Primary data is obtained from observation data and in-depth interviews with *Subak* administrators and experts. While secondary data is obtained from library/literature studies related to the research topic and data from field observations. Knowledge formation is carried out through ontology modeling, which produces a vocabulary dataset.

B. *Ontology Development:*

The collected data is in the development stage of the reference model in CIDOC-CRM conceptual modeling. It consists of two stages, namely:

1) *Knowledge Conceptualization*

Knowledge will be modeled based on ontology. The concept of knowledge ontology[30] has several main components, namely:

- *Classes*: Explain the concept and general things of knowledge in a domain. A class has subclasses intended to express more specific concepts than the superclass.
- *Properties*: are 2-way relations that connect classes with other classes to form knowledge/concept links. There are two types of ontology properties: object properties that connect objects with other objects and data type properties that connect objects with data type values (text, string, or number).
- *Instance /particular things /objects* are individuals /members, are actual objects of a class containing facts/information from a concept / knowledge.
- *Constraints* or rules for the things
- *Relationship* is the concept of the relationship between the things
- *Functions* are processes that involve things.

2) *Knowledge Modeling:* will be formed in OWL, which allows users to define concepts, properties, and relationships between these concepts in more detail and formally. Protégé is used to help visualize the concept of knowledge. This stage produces ontology class structure and ontology graph.

C. *Ontology Assessments*

This is the stage of implementing the evaluation and validation of the ontology produced. This stage produces recommendations for ontology enrichment. Validation is done using OntoQA (Ontology Quality Analysis) [31] and experts' comments. OntoQA is one technique used to evaluate ontology's quality. OntoQA provides ontology characteristics as a description of the quality of the ontology in terms of knowledge representation potential. The OntoQA used in this study is the OntoQA measurement scheme category, which consists of Relationship Richness (RR), Inheritance Richness (IR), and Attribute Richness (AR) measurements.

1) *Relationship Richness (RR):* is a metric used to describe the relationships used in ontology. This metric measures how ontology utilizes various relationships between existing concepts, inheritance, and non-inheritance relationships. RR indicates whether ontology relies on inheritance hierarchies or utilizes various types of non-hierarchical relationships to represent knowledge. The RR evaluation will describe the ratio between the number of inheritance (SC) and non- inheritance (P) relationships on a scale of zero to one, formulated in equation 1.

$$RR = \frac{|P|}{(|SC| + |P|)} \quad (1)$$

RR provides important insights into the complexity and flexibility of the relationship structure in an ontology and can be used as one indicator of the quality of an ontology in representing knowledge in a particular domain.

2) *Inheritance Richness (IR)*: is a metric used in ontology evaluation to measure the depth of the inheritance hierarchical structure in ontology. This metric indicates how much ontology utilizes inheritance relationships among its concepts. Inheritance Richness (IR) is the ratio of the total number of subclasses (H) in ontology to the total number of classes (C) on a scale of zero to one. The IR formula is presented in Equation 2.

$$IR = \frac{|H|}{|C|} \quad (2)$$

3) *Attribute Richness (AR)*

Attribute Richness (AR) is a metric used in ontology evaluation to measure the extent to which ontology utilizes attributes or properties in describing its concepts. Attribute Richness (AR) measures the average number of attributes (att) possessed by each class (C) in ontology. This metric provides an overview of how rich the description of concepts in an ontology is based on the number of attributes used. The AR formula is presented in Equation 3.

$$AR = \frac{|att|}{|C|} \quad (3)$$

D. *Ontology Enrichment*

This is the stage of completing and enriching concepts and information data for the adequacy of the knowledge population based on recommendations generated from the previous stage. There are two types of enrichment[17], namely:

1) Carried out at the beginning of ontology development to obtain sufficient knowledge. This study will carry out this type of enrichment. Ontology development is a repetitive process until the targeted knowledge adequacy is achieved for creation. This stage will return to the ontology development stage, and it is possible to skip certain stages if deemed unnecessary.

2) Enriches ontology by adding domains to an already existing one, aiming to produce a new ontology or an ontology with an expanded domain.

III. RESULT AND DISCUSSION

The development of knowledge management requires a knowledge representation model, where the implementation of ontology is one solution to capture knowledge [7] that has yet to be documented. As a formal knowledge model, ontology provides a framework for defining concepts, relations, properties, and rules in the knowledge domain [5]. This allows for consistent organization and interoperability and computer understanding of the context and meaning of knowledge so that it can be used more effectively for various needs. Following the research framework (Fig 2), four main stages exist in developing the *Subak* ontology model[17]. The ontology was built using Balinese language representation, considering that many *Subak* terms are terms used by Balinese people in their traditional life. The following is a series of steps taken in ontology development.

A. *Requirement Analysis*

Determining the ontology's objectives, domain, and scope is the first step in focusing on the scope of knowledge. This is followed by determining the objectives of ontology formulation and acquiring the knowledge domain.

1) *Objective Formulation*

The main objective of ontology formation is to represent *Subak* knowledge as a cultural heritage that must be preserved. Furthermore, the limitations and scope of ontology are declared. This research focuses on the *Subak* domain as depicted in Fig. 2, which shows the scope of ontology, which is depicted in a Conceptual Data Framework.

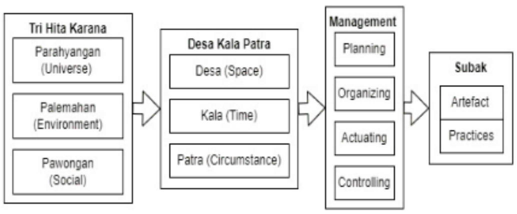

Fig 3. Conceptual Data Model of *Subak* Knowledge

Next, competency questions are compiled to deepen understanding of the scope of the ontology domain being developed. In addition, it will also be used in the ontology validation stage. CQs in Table 2 are questions that must be answered by the knowledge base built from the ontology being developed. CQs are created based on observations, documentation studies, and expert interviews.

The general definition of *Subak* is determined to be an organization that manages traditional irrigation systems in Bali based on the principles of Tri Hita Karana [30], including social, cultural, ecological values and agricultural practices related to it. Therefore, the compiled CQ must be able to explore knowledge in related elements [31]. Table 1 is a list of the established CQs.

TABLE I
COMPETENCY QUESTIONS

Elements	Competency Questions
Tri Hita Karana	What is the Definition of *Subak* in the Parahyangan concept?
	What is the Definition of *Subak* in the Palemahan concept?
	What is the Definition of *Subak* in the Pawongan concept?
Pawongan (Social)	Who plays a role in the *Subak* organization?
Pawongan (Social)	What are the activities in the *Subak* organization?
Palehaman (Environment)	What infrastructure is involved in the *Subak* irrigation system?
Palemahan (Environment)	How is the *Subak* irrigation system organized?
Palemahan (Environment)	What is the irrigation pattern carried out by *Subak*?
Parahyangan (Traditional Ceremonies)	What are the ritual elements associated with *Subak*?
Parahyangan (Traditional Ceremonies)	Where are the ritual ceremonies carried out by *Subak*?
Pawongan (Social)	What is the organizational structure of *Subak* management?
Pawongan (Social)	What is the pattern of communication and coordination between *Subak* members?

2) *Domain Acquisition*

This stage is the stage of acquiring knowledge in the knowledge domain. The data collected in the objective formulation stage is mapped into the data mapping concept relation depicted in Fig. 2. It begins with the Tri Hita Karana Concept as the basic principle of *Subak* activities. Each aspect of Tri Hita Karana has its Desa-Kala-Patra elements. In each activity, the Desa-Kala-Patra elements are categorized in modern management activities based on POAC (Planning-Organizing-Actuating-Controlling). These management activities include defining activities and artifacts.

Data collection methods through observation, surveys, focus group discussions (FGD), and documentation studies. Because the *Subak* ontology has never been created, the acquisition is carried out from the beginning (scratch). This stage begins by collecting all the vocabulary related to *Subak* through document studies, field observations, and in-depth interviews with several experts. The data collection techniques used are:

- *Document Study*: Various documents and literature have been studied, including lontar, awig-awig *Subak*, government regulations, Village Regulations, and other documents obtained from online sources or directly from sources.
- *Observation:* Participant observation is carried out on *Subak* organizations, both internal and external, to support the analysis carried out in the study.
- *In-depth interview:* used to collect qualitative data. In-depth interviews conducted with *Subak* administrators, farmers, community practitioners, and experts. Given that understanding *Subak* requires a postmodern approach[26], [27], which recognizes the complexity, diversity of perspectives, and challenges in maintaining tradition amidst rapid social and economic change, the selection of informants is determined based on purposive sampling. The essential criteria for informants are that they have been involved in the *Subak* field for over two years. The determination of experts consists of experts in the fields of *Subak*, ecotourism, and socio-culture.

The data collected is then mapped according to the data mapping concept relation domain depicted in Table 2.

TABLE II
ONTOLOGY SCOPE

Tri Hita Karana	Desa Kala Patra	POAC	Identification

Parahyangan (Universe)	Desa (Place)	Planning	Planning the construction and maintenance of sacred places
		Organizing	Management of sacred places
		Actuating	Use and maintenance of sacred places
		Controlling	Supervision of management of sacred places
	Kala (Time)	Planning	Planning of traditional ceremony schedules
		Organizing	Management of traditional ceremony times
		Actuating	Time of implementation of traditional ceremonies
		Controlling	Supervision of management of traditional ceremony times
	Patra (Activity)	Planning	Planning of traditional ceremony activities and ceremonial equipment
		Organizing	Management of traditional ceremony activities and ceremonial equipment
		Actuating	Implementation of traditional ceremonies and ceremonial equipment
		Controlling	Supervision of implementation of traditional ceremonies and ceremonial equipment
Palemahan (Environmental))	Desa (Place)	Planning	Planning of construction and maintenance of irrigation structures
		Organizing	Management of irrigation structures
		Actuating	Use and maintenance of irrigation structures
		Controlling	Supervision of management of irrigation structures
	Kala (Time)	Planning	Planning of schedule for implementation of irrigation management
		Organizing	Management of irrigation management time
		Actuating	Time of implementation of irrigation management
		Controlling	Supervision of management of irrigation management time
	Patra (Activity)	Planning	Planning of irrigation management activities and irrigation equipment
		Organizing	Management of irrigation management activities and irrigation equipment
		Actuating	Implementation of irrigation management and irrigation equipment
		Controlling	Supervision of implementation of irrigation management and irrigation equipment
Pawongan (Social Organization)	Desa (Place)	Planning	Planning of construction and maintenance of organizational management places
		Organizing	Management of organizational management places
		Actuating	Place of implementation of organizational management
		Controlling	Supervision of place of implementation of organizational management
	Kala (Time)	Planning	Planning of schedules implementation of organizational management
		Organizing	Management of organizational management implementation time
		Actuating	Implementation of organizational management
		Controlling	Supervision of organizational management implementation time
	Patra (Activity)	Planning	Planning of organizational management activities and parties involved
		Organizing	Management of organizational management activities and parties involved
		Actuating	Implementation of organizational management activities and parties involved
		Controlling	Supervision of the implementation of organizational management activities and parties involved

B. *Ontology Development*

This stage is the development stage of the ontology model referring to CIDOC-CRM conceptual modeling. It consists of two stages, namely:

1) *Knowledge conceptualization*

This stage produces entity classes, object and data properties, and individuals from each entity. Ontology *Subak* consist of 18 Super Classes, 76 Sub Classes, 21 Object Properties and 366 Data Properties. Object properties define the relationship between classes, where Subclass is an inheritance relationship. Data Properties is properties of data that represent atribut of the class.

2) *Ontology Modelling*

The modeling stage is performed by the Protégé. The structure of the *Subak* ontology class is shown in Fig 3. Meanwhile, Fig 4 is an ontograph that describes all superclasses. Ontograph is a feature in Protégé that can map relations in ontology. Figure 5 illustrates an ontograph of all superclass, and Fig 6 describes the *Palemaman* class and its relations. Protégé also has a feature to generate OWL (Ontology Web Language). OWL is a form of ontology designed for use by applications.

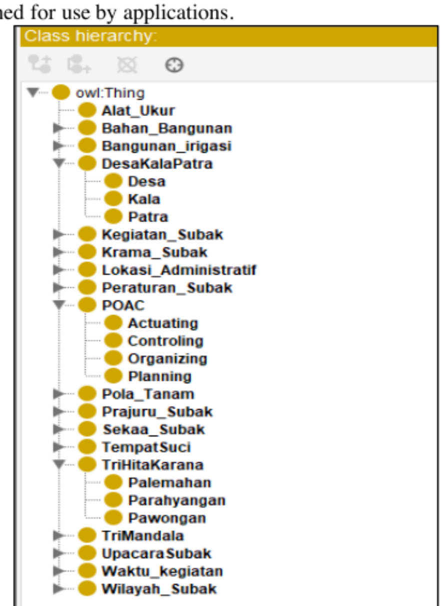

Fig 4 *Subak* Ontology Class Structure

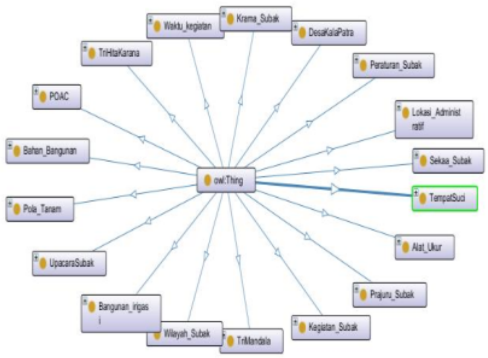

Fig 5 OntoGraph of SuperClass

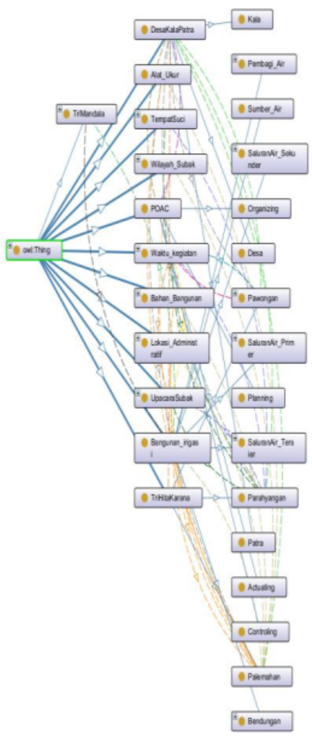

Fig. 6 OntoGraph of SuperClass Palehaman

C. Discussion of Ontology Assessments and Enrichment

Ontology assessment using OntoQA which measures three key aspects: Relationship Richness (RR), Inheritance Richness (IR), and Attribute Richness (AR). The result of the assessment will be a recommendation for the enrichment stage.

1) Relationship Richness (RR)

This metric helps identify the diversity of relationships in an ontology, which indicates the complexity and similarity of knowledge representation. As describe in knowledge conceptualization, the developed ontology contains 76 non-inheritance relationships and 21 subclasses (inheritance relationships).

TABLE III
RELATIONSHIP RICHNESS

Inheritance Relationships (SC)	Non-inheritance Relationships (P)	Relationship Richness(RR)
21	76	0.8

Table 3 presents the calculation based on equation 1, which result of RR value of 0.8 for *Subak* ontology. With range from 0 to 1, RR values close to 1 indicate that most of the relations are non-inheritance relations. RR value of 0.8 indicates that *Subak* ontology is relatively knowledge-rich, containing more non-inheritance relationships. Ontologies with a higher proportion of non-inheritance relationships represent more information than those dominated by inheritance relationships[32]. The *Subak* ontology utilizes various types of non-inheritance relationships to represent knowledge. This indicates that *Subak* ontology is more complex and flexible, and can capture relationships between concepts to hierarchical structures.

Meanwhile, RR values close to zero indicate that most of the relations in the ontology are inheritance relations, meaning that the ontology structure relies heavily on hierarchy. The ontology focuses more on inheritance or hierarchy relationships between concepts, which can be suitable for domains that require a strong hierarchical structure but may be less able to describe more complex and contextual relationships[31].

2) Inheritance Richness (IR)

Ontology *Subak* consist of 94 Classes with 76 are subclass. Using equation 2, which result of IR value of 0.78 for *Subak* Ontogoly (Table 4).

TABLE IV
INHERITANCE RICHNESS

Sub-Class (H)	**Class (C)**	**Inheritance Richness (IR)**
76	94	0.78

The ontology utilizes hierarchy and inheritance between concepts moderately in the ontology structure to organize knowledge better, allowing for a more structured and detailed knowledge representation[33]. Table 4 presents the calculation IR based on equation 2, which results in an IR value of 0.78 for *Subak* ontology. With values ranging from 0 to 1, IR values close to 1 indicate that most classes in the ontology have subclasses. IR value of 0.78 indicating that *Subak* ontology has a more complex and deep hierarchical structure, for more structured and detailed knowledge representations. Meanwhile, IR values close to zero indicate that most classes in the ontology are independent classes, with few or no related subclasses[34].

3) Attribute Richness (AR)

Table 5 presents the calculation based on equation 3, which result of AR value of 3.89 for *Subak* ontology.

TABLE V
ATTRIBUTE RICHNESS

Attributes (Att)	Class(C)	ATTRIBUTE RICHNESS
366	94	3,89

This AR value of 3,89 indicates that *Subak* ontology provides fairly rich description of attributes with each class having an average of 3 to 4 attributes. High AR indicates that the ontology provides a rich description of attributes for each class[33]. This allows for a deeper understanding of the concepts by providing more contextual and descriptive information. Meanwhile, low AR indicates that the ontology has a simpler description of the concepts, with fewer attributes that may only cover basic information. Attributes are usually used to describe specific characteristics of a concept, such as color, size, location, or relationships with other concepts[35]. Attributes are essential elements in an ontology because they provide additional information or features that enrich the definition of each concept[5]. In some cases, this may be sufficient for specific domains, but in other domains, the lack of attributes can be a limitation in knowledge modeling.

4) Enrichment

From the results of discussions with experts, it was found that the representation of knowledge in the *Subak* ontology that was built was quite feasible. In addition, from the results of the ontology assessment that has been built, this study will be continued with knowledge enrichment to obtain the expected knowledge adequacy and then implement it into KMS-based knowledge. Enrichment will be done by enriching instances, and it is also possible to include data and object properties. The adequacy of ontology knowledge is intended to answer CQs whose suitability will be confirmed by experts.

IV. Conclusion

The *Subak* ontology model will be implemented as a knowledge base for the *Subak* knowledge management system. The ontology is built based on *Subak*'s approach as an organization based on traditional philosophy (Tri Hita Karana and Desa-Kala-Patra) and the application of modern management (POAC). The ontology model consists of class hierarchy, object properties (relations), data properties (attributes), and instance (individual entities).

The *Subak* ontology was evaluated using Ontology Quality Analysis and focus group discussions with experts. The evaluation results show that Relationship Richness (RR) value is 0.8, Inheritance Richness (IR) value is 0.78, and Attribute Richness (AR) value is 3.89. The ontology produced is quite rich and carries knowledge with specific characteristics, with not too many attributes for each class. Experts' comments stated that the ontology model created is worthy of being used to represent knowledge in the *Subak* Knowledge Management System.

The resulting framework can be a reference for further similar research in developing ontology from scratch related to heritage cultural preservation. The resulting *Subak* ontology can be a reference as a knowledge base for the development of other ontologies in the domains of agricultural management, social organization, and cultural preservation. This study supports the preservation of *Subak* culture so that it is known to future generations.

Acknowledgment

We would like to thank the Directorate General of Higher Education, Research and Technology, Ministry of Education, Culture, Research, and Technology, through Research Contract Number: 102/E5/PG.02.00.PL/2024.

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