Enabling Cultural Heritage Preservation: A Semantic Web Prototype for Digitizing and Documenting Balinese Woven Fabric Artifacts

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Abstract. Balinese woven fabric holds significant cultural value, serving as a staple in everyday attire for schools and offices in Bali. However, crucial information about these artifacts, including motifs, categories, and raw materials, remains inadequately documented. This research focuses on the development of a Balinese woven fabric information system using the Prototyping system development method to address this gap. The unique motifs of Balinese woven fabric, expressed through geometric shapes, play a pivotal role in defining its characteristics. These motifs, rooted in the beliefs of the Balinese people, contribute to the cultural richness of the region. A prototype system was developed to systematically document and preserve this cultural heritage, featuring browsing and search functionalities. Data on Balinese woven fabric was gathered through interviews and direct observation, forming the basis for the prototype's ontology. The ontology serves as the backbone of the system, representing the intricate knowledge associated with Balinese woven fabric. Black-box testing was employed to evaluate the system's functionality, ensuring a robust and user-friendly interface. To assess user acceptance, the Technology Acceptance Model (TAM) was applied, focusing on the searching, and browsing features. A total of 35 respondents participated in the evaluation, providing valuable insights. The results indicate a consensus among participants that the proposed prototype system is both easy to use and highly useful, affirming its potential as a valuable tool for preserving and navigating the rich cultural tapestry of Balinese woven fabric artifacts.

Keywords: Balinese woven fabrics, semantic web, prototyping, cultural heritage, ontology.

1 Introduction

The island of Bali, situated within the vast Indonesian archipelago, stands out among thousands of islands as one of the smallest provinces. Geographically positioned 18 degrees north of the westernmost tip of Australia and 8 degrees south of the equator,

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Bali spans an area of 5,634 square kilometres with an impressive 529 kilometres of coastline. Divided into eight regencies (*kabupaten*) and one municipality (*pemerintahan kota*), the island experienced a significant population surge, nearly doubling from 2009 to 2023 with the projected population of Bali in 2023 expected to reach 4.3 million, with an average annual growth rate of 1.01%.

Bali stands out as a prominent global tourist destination, renowned for its distinctive culture. One of its main attractions lies in the preservation of its unique cultural heritage, which is predominantly upheld through daily practices and religious rituals that breathe life into traditions of the past [1]. This cultural legacy is transmitted across generations, ensuring that each succeeding cohort learns, through hands-on experience, the intricate processes integral to Balinese customs and traditions. Despite this commitment, Mexican artist Miguel Covarrubias, in his 1937 book "Island of Bali," voiced concerns about the potential demise of Balinese living culture, fearing it might succumb to the relentless pressures of modern commercialism and standardization [2]. Compounding this apprehension is the accelerated cultural erosion in Bali, driven by a tendency towards inadequate historical documentation and a heavier reliance on myths within the Balinese narrative.

Balinese woven fabric (see **Fig. 1**) holds profound cultural significance, functioning as a fundamental component of everyday attire for schools and offices in Bali. Despite its importance, critical details about these artifacts, such as motifs, categories, and raw materials, remain insufficiently documented. The distinctive motifs adorning Balinese woven fabric, characterized by intricate geometric shapes, play a pivotal role in defining its unique identity. These motifs, deeply rooted in the Balinese belief system, contribute significantly to the cultural richness of the region. Regrettably, a scarcity of information exists on the internet regarding this valuable cultural heritage, with much of the knowledge being tacit and embedded within the local community. Efforts to enhance the documentation and accessibility of this cultural treasure are essential for its preservation and wider appreciation. Recently, scholars and communities have undertaken initiatives to digitally preserve Indonesian knowledge, aiming to ensure its accessibility for younger generations [3-5].

Fig. 1. Example of Balinese woven fabrics

This research focuses on the documentation and preservation of both facets, namely artifacts and practices, of cultural heritage knowledge. Leveraging technological advancements, including the Internet, smartphones, and progress in information technologies, offers a distinctive, crowd-driven solution to address this challenge. Adopting a systematic, crowd-driven approach to collect, store, verify, and organize cultural information, our goal is to integrate diverse heritage knowledge and associated practices. Through an appropriate framework and platforms, we aim to widely disseminate this wealth of cultural information and evaluate the accuracy, validity, and utility of our approach in preserving and extending cultural heritage, particularly in the context of Balinese woven fabric.

Cultural heritage knowledge encompasses a multitude of interconnected concepts and information. Numerous studies propose that employing ontologies can serve as an effective tool for depicting and capturing historical knowledge, as well as managing and conserving cultural heritage assets in digital formats [6]. The utilization of an ontology to store and represent the intricate relationships among digital heritage-related concepts facilitates the sharing and reuse of pertinent digital resources across diverse computer applications [7]. Furthermore, adopting an ontology-based approach allows for flexibility in knowledge expansion when cultural knowledge is accumulated incrementally. Consequently, formal reasoning can be applied as this knowledge evolves.

2 Methodology

An Information System (IS) is composed of individuals, structures, technologies, and work systems, strategically introduced in an organization to enhance its efficiency and effectiveness. Behavioural science within the IS discipline is dedicated to formulating and validating theories, primarily relying on natural science research methods. In contrast, design science in IS serves as a problem-solving discipline, drawing from both engineering and the sciences of the artificial domain. The objective of design science research is to actualize innovative concepts for addressing problems, involving phases like analysis, design, development, implementation, and evaluation. Six critical considerations in design science research encompass (1) the identification and precise depiction of the IT problem, (2) demonstration that no viable solutions currently exist, (3) crafting and presenting a novel IT artifact to tackle the issue, (4) evaluating and assessing the IT artifact, (5) comprehending the value added by the solutions, and finally, (6) providing an explanation of the implications and benefits for the organization and community.

The Design Science Research Methodology (DSRM) provides a valuable framework for our investigation, as it endeavours to construct and assess Information Technology artifacts specifically designed to address complex problems [8]. Furthermore, it frequently emphasizes studying an IT artifact as the central focus. The DSRM involves several stages (see **Fig. 2**), including problem identification and motivation, formulation of solution objectives, design and development, demonstration and evaluation, and communication. Given the nature of our research, this methodology is considered the most appropriate choice, aligning seamlessly with our objectives.

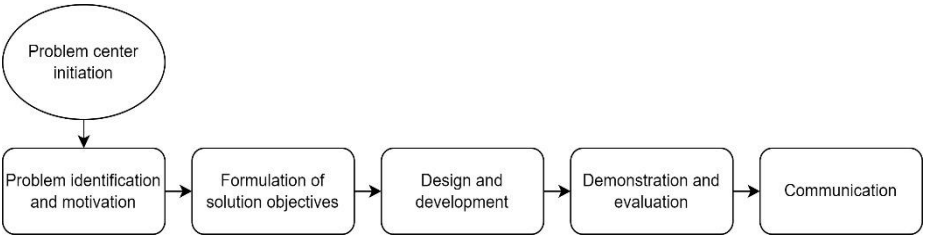

Fig. 2. Design Science Research Methodology

Problem center initiation. This research commences by adopting a problem-center initiation approach. An exploration of existing literature and discussions with the Balinese community reveal a significant challenge: the erosion of cultural knowledge among the Balinese people. This issue arises from the traditional method of transferring cultural knowledge through socialization, specifically from tacit to tacit. The current approach is deemed inadequate, as current Balinese youth increasingly rely on technological means, such as the Internet, for knowledge acquisition. Without systematic digitization and documentation of cultural knowledge, the richness and diversity of Balinese cultural heritage are at risk of diminishing over time.

Problem identification and motivation. Given the diverse and non-standardized nature of Balinese woven fabric artifacts, it is crucial to comprehend and encapsulate the information within the appropriate context. Utilizing a semantic web system approach becomes essential for integrating this data into an accessible format. Such a system not only aids in organizing but also facilitates comprehensive and systematic access to cultural knowledge. Subsequently, innovative approaches like community-based crowdsourcing can effectively tap into knowledge sources, including cultural heritage experts and community understanding, thereby enhancing the overall preservation and dissemination of Balinese cultural insights.

Formulation of solution objectives. The primary aim of this research is to create, assess, and validate a proof-of-concept-level semantic web prototype. This prototype is designed to facilitate a collaborative platform where multiple users can engage in learning, sharing, sorting, refining, and representing cultural knowledge and related practices over the Internet. The ultimate goal is to foster the expansion and enrichment of cultural insights through this innovative platform.

Design and development. This phase involves the creation of the prototype, employing the prototyping method as the chosen approach. This method lies in facilitating interaction between developers and users throughout the prototype creation process. The research advances through various stages, starting with Requirements Analysis, followed by Data Collection, Model Building, System Development and Design, and culminating in System Design. Concurrently, the development of ontology, serving as the backbone of our semantic web, is a focal point in this stage. Ontologies play a crucial role in fostering communication among diverse application systems and enhancing interoperability. They achieve this by establishing a shared understanding of

a domain, with a set of terms explicitly representing concepts and their specific meanings within the ontology.

Demonstration and Evaluation: Upon completion of the prototype artifact, we conducted an assessment using Black box testing to thoroughly evaluate the system's functionality, aiming for a robust and user-friendly interface. In addition to this, we sought to gauge user acceptance by inviting a carefully selected group to interact with the prototype. The evaluation utilized the Technology Acceptance Model (TAM) [9, 10], with a specific emphasis on assessing the effectiveness and usefulness of the searching and browsing features.

Communications: This final stage of the methodology involves presenting and publishing the study's outcomes in academic outlets, proceedings, and journals. Through this dissemination, we aim to contribute valuable insights to the relevant academic community.

3 Results and Discussion

3.1 Ontology Development

Data collection for the ontology involved conducting interviews with the owners of Balinese weaving fabric production in the Klungkung district and with a Professor from the Indonesian Institute of Arts (ISI) acknowledged as an expert in Balinese weaving fabric. The interview outcomes offer insights into the constituent components of the Balinese woven fabric artifact. The authors incorporate this information into the system design, with these components comprising:

1. **Motif or pattern:** Aesthetic appeal in Balinese woven fabric involves the skillful arrangement of decorative elements such as faunal, figurative, floral, and geometric motifs. These motifs contribute to the visual richness and complexity of the Balinese woven fabric design.
2. **Material:** The thread selection plays a pivotal role in crafting Balinese woven fabric cloth, with two primary types—cotton and silk threads. The choice of material significantly influences the texture and overall quality of the Balinese woven fabric.
3. **Comb:** Iron and wire combs are integral tools in determining the density and thickness of Balinese woven fabric cloth. The quantity of combs, categorized as comb 70 and 80, directly correlates with the fabric's density. More combs result in a superior level of thickness.
4. **Axles (details of the motif/pattern):** Precision in crafting the axles motif enhances the clarity of the Balinese woven fabric cloth pattern. Appreciating this detail may require an in-person inspection, as the intricacies of the threads can be challenging to discern from photographs. Axles, categorized as axle 2, axle 3, and axle 4, contribute to the level of sharpness and detail, with smaller axles indicating finer patterns.
5. **Fabric size:** Standard dimensions for Balinese woven fabric cloth typically range from 2.25 x 1.5 meters to 2.25 x 1.05 meters. While these sizes align with

common production standards, variations may exist, reflecting diverse practices in different contexts.

6. **Color:** The color palette of Balinese woven fabric cloth is diverse, featuring an array of hues such as red, black, blue, green, yellow, brown, purple, and more. These colors are foundational to the fabric's aesthetic appeal, contributing to its overall visual impact.

3.2 Ontology Implementation

Once the information about Balinese woven fabric was collected from cultural experts, we proceeded to conceptualize, as depicted in **Fig. 3**, and subsequently formalize and implement the ontology as shown in **Fig. 4**. This process followed the Methontology ontology development method [11]. Furthermore, we integrate the kulkul framework, encompassing *Tri Hita Karana* and *Desa Kala Patra* principles [1, 12], into our ontology for Balinese fabric weaving.

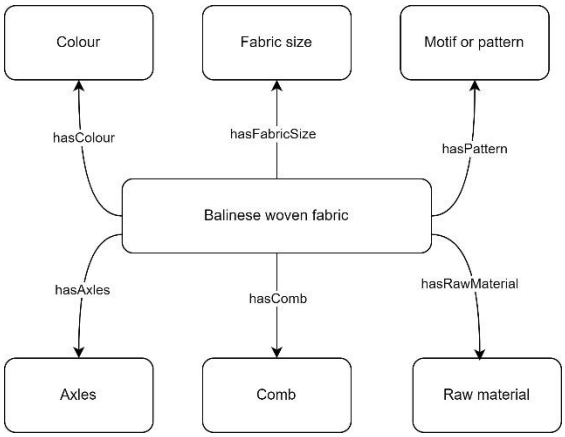

Fig. 3. Balinese woven fabric ontology conceptual

Creating an ontology necessitates a thoughtful conceptualization of its structure. This involves defining the triplet pattern within the ontology, which constitutes linking individual entities to form a pattern comprising subject, predicate, and object. This intricate relationship is explained through a visual representation (see **Fig. 5**), where the subject, represented by the individual woven fabric (*Endek_Bunbunan*)," is connected to object property hasMotif (*memilikiMotif*) as a predicate, and connected to object individual Flora. The result is a comprehensive depiction of the ontology, capturing the nuanced interplay between these essential components in a visually accessible manner. Finally, our ontology consists of 1156 set of triples and loaded the triple store on our server.

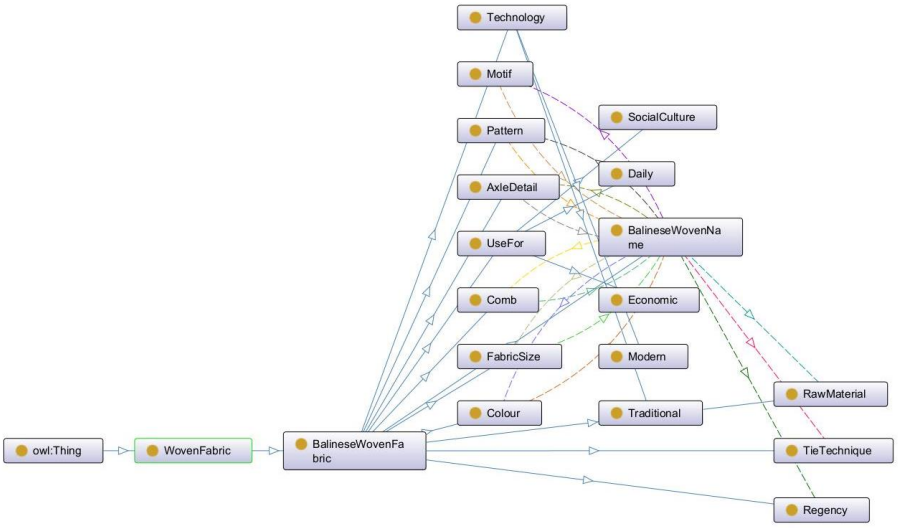

Fig. 4. Balinese woven fabric ontology visualization

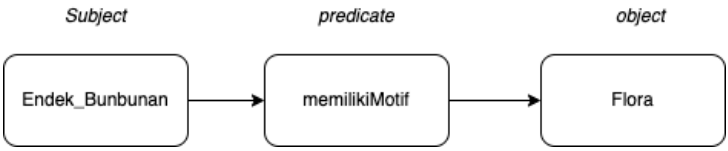

Fig. 5. Example of triplet pattern for the Balinese woven fabric

Here is a sample of the OWL representation in Turtle triple syntax serialization (TTL), designed for easy readability, to depict the details of a Balinese woven fabric.

```
@base <http://ccbp.oss.web.id/BalineseWoven#>.
<http://ccbp.oss.web.id/BalineseWoven> rdf:type owl:Ontology .
###  http://ccbp.oss.web.id/BalineseWoven#Endek_Bunga_Prada
:Endek_Bunga_Prada rdf:type owl:NamedIndividual ,
:KainEndek ;
:berasalDariKabupaten :Klungkung ;
:memilikiAs :As_4 ;
:memilikiCorak :Bunga ;
:memilikiMotif :Flora ;
:memilikiSisir <http://ccbp.oss.web.id/BalineseWoven#70> ;
:memilikiUkuranKain            <http://ccbp.oss.web.id/Balinese-
Woven#2.25x1.05m> ;
:memilikiWarna :Coklat ;
:menggunakanAlat :ATBM ;
:menggunakanBahan :Benang_Sutra ;
```

```
:menggunakanTeknik :Single_Ikat ;
:memilikiDeskripsi "Endek ini memiliki corak bunga modifikasi
dengan ciri khas menggunakan tinta prada dalam pembuatan coraknya.
Dan dalam pewarnaannya endek ini menggunakan cat pewarna tekstil
yang berwarna coklat" ;
:memilikiGambar "Endek_Bunga_Prada.JPG".
```

The evaluation phase stands as a pivotal component within our methodology, serving the purpose of assessing the Balinese woven fabric ontology. Employing the Protégé 5.5.0 ontology editor application, we leverage the Reasoner add-on to meticulously scrutinize the consistency of our meticulously designed ontology. The conclusive outcomes of this evaluation affirm the absence of errors within our developed ontology, leading us to confidently assert its overall coherence and reliability.

3.3 Prototype Implementation

Once the Balinese woven fabric ontology was finalized, we proceeded with the development and implementation of this ontology into our semantic web prototype. The prototype is now accessible online at https://woven.oss.web.id. Our choice for ontology triple store storage is Apache Jena Fuseki. The semantic web frontend has been developed using the PHP language, and to facilitate communication between the triple store and our PHP frontend, we have seamlessly integrated the EasyRDF API. The prototype provides three key features:

1. **Semantic Browsing:** This entails quickly perusing a set of information without a specific purpose, guided by the ontology hierarchy.
2. **Semantic Searching:** Users can explore information based on the semantic ontology relationships embedded within the system.
3. **Simple Searching:** Similar to semantic searching, users can input any word into the system, prompting it to search for relevant information within the ontology.

3.4 Evaluation

Upon completing the system implementation on our commercial Virtual Private Server (VPS), we proceeded with a comprehensive evaluation. Two distinct methodologies were employed: firstly, Black-box testing was utilized to scrutinize the system's functionality, ensuring the development of a robust and user-friendly interface. This evaluation phase involved collaboration among authors and system developers. Secondly, for assessing user acceptance, we applied the Technology Acceptance Model (TAM), with a specific focus on the searching and browsing features. TAM is a well-established model used to gauge user acceptance of information systems [13, 14], employs two key variables—perceived usefulness and perceived ease of use—to elucidate user attitudes toward utilizing an information system. Each variable, consisting of six questions, was measured using a 7-point Likert scale (7 = strongly agree, to 1 = strongly disagree), as recommended by Vagias [15] A total of 35 respondents from the Udayana university

network were invited from to participate in the evaluation, providing valuable insights. Upon agreeing to participate in our study, participants are provided with information and a tutorial to acquaint themselves with the prototype. Once they are familiar with the system, they are assigned 10 tasks—comprising 5 browsing tasks and 5 searching tasks—to answer questions using the prototype. Subsequently, upon completing the tasks and finding the answers, participants are then prompted to respond to a set of questions related to the Technology Acceptance Model (TAM).

The evaluation of the user-perceived ease of use variable reveals an impressive average score of 6.54 on a 7-point scale, with none of the participants providing a score below the midpoint of 4. This suggests that the majority of users find the prototype exceptionally easy to use. Furthermore, the assessment of the perceived usefulness variable, with an average score of 6.50, indicates that the system proves valuable to users when seeking answers to the questions posed by researchers. These results highlight a unanimous agreement among participants regarding the user-friendliness and high utility of the proposed prototype system. This consensus strongly affirms its potential as a valuable tool for preserving and navigating the intricate cultural tapestry of Balinese woven fabric artifacts.

4 Conclusions

This research delves into a specific facet of Balinese cultural heritage—namely, the artifacts of Balinese woven fabric. Our contributions encompass the development of knowledge representation through a semantic ontology and the creation of a Semantic Web Prototype for the Digitization and Documentation of Balinese Woven Fabric Artifacts.

To validate our prototype, we employed two evaluation methodologies. Black-box testing was utilized to scrutinize the system's functionality, ensuring the establishment of a robust and user-friendly interface. Concurrently, we applied the Technology Acceptance Model (TAM) to gauge user acceptance, with a specific focus on the searching and browsing features. A total of 35 respondents actively participated in the evaluation, providing valuable insights. The findings reveal a consensus among participants, affirming that the proposed prototype system is both user-friendly and highly useful. This collective agreement underscores its potential as a valuable instrument for preserving and navigating the intricate cultural tapestry of Balinese woven fabric artifacts.

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