CULTURAL HERITAGE PRESERVATION THROUGH ONTOLOGY-BASED SEMANTIC SEARCH SYSTEMS

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1. Introduction

For centuries, the Angkor civilization has been a dominant influence in Mainland Southeast Asia (MSEA). It is generally known as the antecedent of the Funan Empire and Chenla Empire cultures, which bestowed the area with several awe-inspiring architectural heritage sites. It was these cultures that influenced the architectural establishment in this region, based on the beliefs and traditions of that period. The two Empires systematized the creation, design, and construction of the buildings and structures, and encompassed the architects, builders, designers, and craftsmen who collectively shaped the architectural landscape based on the prevailing styles and techniques of that particular period and culture. The architecture also included a number of temples, monasteries, once-lost cities, and an extensive network of canals, reservoirs, bridges, and road infrastructures.

Thousands of these heritage sites existed and were scattered throughout Cambodia, Laos, Thailand, and across the Mekong River to Vietnam. Owing to their geographical position some of the enormous temples, such as the Banteay Chhmar temple and Preah Khan temple, with entire temple cities, such as the Koh Ker temples and Sambor Prei Kuk temples, were protected because they were built in isolated areas, nestled in the jungle and hidden from mass commercial tourism. Over the years, mosses have gradually covered and almost obscured these structures, as they are often found in out of the way areas. This rich tapestry of historical evidence is a testament to the grandeur

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and complexity of the civilization which once prospered in this region [1– 4].

The primary objective of this study was to integrate digital humanities methodologies into constructing ontology for the shared knowledge of the Khmer civilization in the Greater Mekong Subregion (GMS) countries. The ontology highlights the tangible cultural heritage (TCH) in these countries and is designed to serve as a pivotal resource for information congregation (i.e. gathering, categorizing, and analyzing) and retrieval. Hence, the study delineates the core aspects of this research for developing ontologies, especially for stone castles in the GMS countries.

As mentioned above, the Khmer civilization once had great influence in the Greater Mekong Subregion, dominant evidence being found in the form of the Khmer stone castles. As opposed to temples, these stone castles are noteworthy for several reasons, including their historical significance, architectural uniqueness, and cultural impact.

1) Historical significance: Khmer stone castles, also known as citadels or fortresses, played a crucial role in the defense and governance of ancient Khmer territories.
2) These structures served as military strongholds, administrative centers, and symbols of power and authority for the Khmer Empire, which flourished in Cambodia and neighboring regions during the medieval period. Their construction and strategic placement reflected the Khmer rulers' geopolitical dynamics and expansionist ambitions.
3) Architectural uniqueness: Khmer stone castles are renowned for their impressive architectural features, including massive stone walls, intricate carvings, and sophisticated hydraulic systems. These structures showcase the advanced engineering skills and artistic craftsmanship of the Khmer civilization, demonstrating their ability to harness natural resources and to adapt to diverse environmental conditions. The design and layout of Khmer castles exhibit a blend of indigenous Khmer styles with influences from neighboring cultures, resulting in a distinctive architectural heritage that continues to captivate scholars and enthusiasts alike.
4) Cultural impact: beyond utilitarian functions, Khmer stone castles hold immense cultural significance as symbols of Khmer identity, resilience, and ingenuity. These monumental edifices served as focal points for religious rituals, royal ceremonies, and communal gatherings, reinforcing social cohesion and spiritual beliefs among the Khmer populace. Moreover, the presence of Khmer castles in the GMS countries reflects the broader cultural exchange and diffusion of ideas across regional networks, highlighting the interconnectedness of the GMS countries' civilizations during the medieval period.

Thus, to effectively organize the knowledge for the ontology, the scope classification, elucidation, concepts, and structural intricacies relevant to the stone castles in the GMS were first constructed, then examined. This classification was instrumental in enhancing understanding and facilitating the search for information regarding these historical structures. Knowledge organization and ontology development were employed in the research methodology to enable the systematic networking of related information to foster data-sharing efficacy. Furthermore, semantic search capability implementation allows users to access and utilize this data more effectively [5]. Therefore, the developed ontology is able to play a significant role in enhancing semantic search system development. This advancement was a crucial step towards addressing and bridging semantic gaps in the subsequent phases of this research for the Khmer stone castles in the GMS countries.

2. Methodology

This study aimed to develop an ontology for knowledge relating to the Khmer stone castles across the countries of the Greater Mekong Subregion (GMS). With the goal of delineating knowledge scope and fostering an inclusive understanding of the Khmer stone castles in these nations, this ontology was an introductory step in enhancing semantic search systems. The study employed the Uschold and King methodology for domain ontology development [6] as the directorial framework and encompassed several key processes as follows:

1) Definition of the objective and scope;
2) Ontology development;
3) Subsequent evaluation and
4) Semantic search system development.

As indicated in the research objective, the study highlighted the findings and insights gained during the ontology development.

In delineating classification, the study results indicated that there were seventy-two (72) classes comprised of ten (10) primary classes which were: *Castle, Location, Country, Khmer art, Art type, Castle size, Castle type, Material, Religion, and Condition*. The study affirmed that the Khmer Stone Castle was interconnected with all other classes as outlined in the Semantic Web Table Specification and adhered to the W3C's RDF standards [7]. The data within the ontology were meticulously organized and presented following the format of a descriptive example, as illustrated in Table 1 and Figure 1. This structured approach facilitated a comprehensive and systematic representation of the information, aligning with best practices in data organization and semantic web standards.

Table 1. List of main classes and definitions

Class/Concept	Definition
Castle	A castle in the context of the Khmer stone castle ontology refers to a fortified structure or complex primarily built during the historical period of the Khmer Empire. These structures, predominantly constructed from stone and characterized by their architectural features, cultural significance and historical value, served various purposes, including religious, administrative, and some residential functions.
Location	This class specifies the geographical coordinates or regional area where the castles are located.
Country	This class indicates the specific country or region within the GMS where the castles are located.

Class/Concept	Definition
Khmer art	This class covers the diverse range of artistic expressions and creations that originated in or are associated with the Khmer culture, primarily in Cambodia. This art form is known for the unique characteristics which emerged over the centuries, particularly during the Angkor period.
Art type	This class describes the specific architectural characteristics and influences evident in the castle's design.
Castle size	This refers to the physical dimensions or scale of Khmer stone castles within the Greater Mekong Subregion (GMS) countries. This class covers the quantitative aspect of the castle's characteristics, including area, the amount of space it occupies, or any other relevant measurements that indicate the overall size of the structure.
Castle type	This refers to the categorization of Khmer stone castles based on distinct architectural styles, historical periods, functional purposes and design characteristics unique to the Greater Mekong Subregion (GMS) countries. This classification helps in the identification, comparison, and analysis of various castle structures within the ontology.
Material	The primary materials used for castle construction include various types of material components, such as wood, brick, and stone (e.g. sandstone, laterite).
Religion	The religious significance or usage of the castle, such as Buddhist or Hindu practices.
Condition	The present state of preservation of the structure.

The Khmer Stone Castle ontology was conducted within Hjørland's knowledge organization concept [8]. The primary focus involved the identification of knowledge categories by delineating concepts and semantic relationships while establishing their connections with relevant concepts. Systematically presenting the outcomes, we organized the data on principal concepts into a hierarchical structure based on related content groups through classification schemes. Subsequently, the data structure underwent further refinement into an ontology.

The domain of ontology development adhered to Uschold and King's conceptual framework [9], encompassing three distinct processes: defining purpose and scope, ontology development, and ontology evaluation.

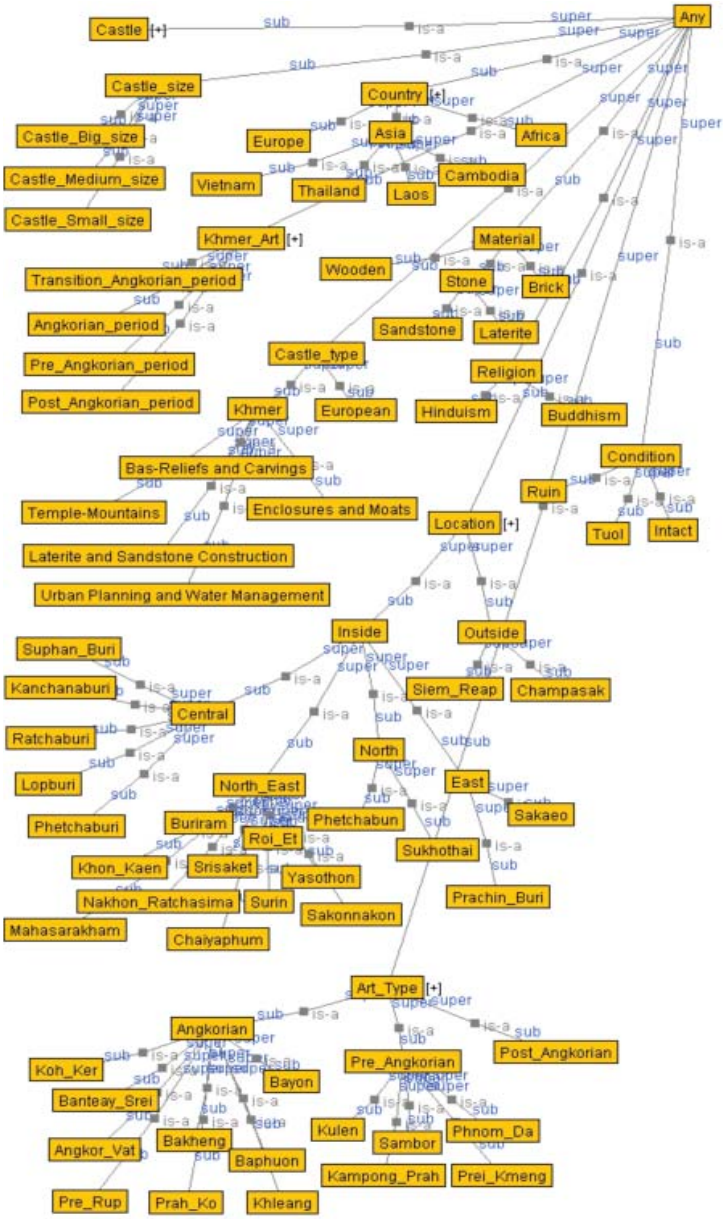

Figure 1. The Khmer Stone Castle ontology

Notably, Noy and McGuinness's seven-step methodology for ontology development [10] was employed, utilizing the Hozo Ontology Editor in this study. Hozo, a graphical ontology editor, was designed in Japan to construct substantial ontologies. The

collaborative effort involved the Department of Knowledge Systems (Mizoguchi Laboratory) and ISIR-Osaka University in conjunction with Enegate Co. Ltd. (Osaka, Japan) [11]. The development and evaluation processes were conducted under the scrutiny of domain experts and application-based evaluation methods.

The approach involved a meticulous process of categorizing knowledge, where the initial steps revolved around identifying the key concepts and their interrelations. These relations were then mapped with relevant concepts, leading to the formation of comprehensive classification schemes. The resultant data hierarchy was a visual representation of the interconnected concepts, laying the foundation for the subsequent development of an ontology. Ensuring a systematic ontology development process, the implementation of Uschold and King's conceptual model [9] involved commencing with the definition of purpose and scope, progressing to the actual construction of the ontology, and concluding with a rigorous evaluation. Noy and McGuinness's well-established seven-step protocol [10] served as a guiding framework throughout this developmental phase. The Hozo Ontology Editor was the instrumental tool employed for its user-friendly graphical interface and ability to handle the intricacies of constructing robust ontologies.

The study utilized WIDOCO [12] to showcase the created ontologies and involved the following steps:

1) Choosing a template for the Ontologies Web Languages file;
2) Inputting metadata, and
3) Uploading the textual data.
4) Upon completion of the preparation, all files relating to the Khmer Stone Castle ontology were uploaded and made accessible at https://ischool.kku.ac.th/owl/index-en.html, as illustrated in Figure 2.

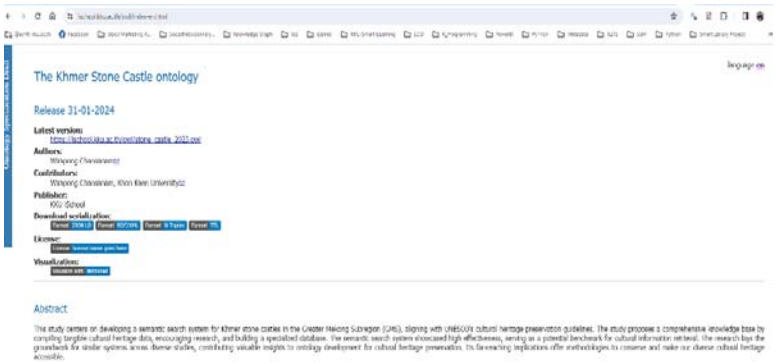

Figure 2. The Khmer Stone Castle ontology by WIDOCO

In this research methodology, an application-based OAM (Ontology-based Application Management) framework was utilized to develop a semantic search and ontology evaluation system that works on web-based technology.

The collected data were processed and analyzed with the application using web-based technology as the data originated from different sources; this technique was adapted for assessing the structure, content, and usability for the ontology development. We developed the semantic search system prototype through the OAM Framework [13], a tool renowned for providing reusable and configurable application

templates for building prototypes.

As a result, the rapid prototyping and hypothesis-testing capabilities of these application templates were particularly noteworthy. Additionally, the OAM framework was integrated with a Web API to enhance the scope for more advanced application development. In the ontology evaluation, moreover, the study employed key information retrieval metrics, such as precision, recall, and F-measure as the crucial metrics for evaluating the accuracy and efficacy of the semantic search system. Correspondingly, in a pivotal aspect, the study adopted information retrieval metrics to evaluate the efficacy of the process of information retrieval in the semantic search prototype.

This evaluation provided insight into the prototype's performance and facilitated the refinement of the approach to ensure appropriate function and user satisfaction. Based on the ontology, this prototype was designed to test and demonstrate how effectively the semantic search system could retrieve relevant information. Therefore, during the study, various tests were conducted to measure key performance indicators such as precision, recall and overall user experience in information retrieval.

3. Results

The aim of this research was to present ontology development designed to encapsulate knowledge of the Khmer stone castles in GMS countries. The ontology was meticulously crafted to define concepts of tangible cultural heritage and to elucidate its relationships, and was dedicated to investigating in-depth cultural heritage content, particularly the Khmer stone castles located in Thailand, Laos, Vietnam and Cambodia. As a pioneer study, this investigation tried to discover and analyze architectural characteristics and historical backgrounds which would contribute to a broader understanding of the regional cultural heritage.

Furthermore, to heighten capacity, a semantic search application was implemented to demonstrate the practical utility of ontology development, which was evaluated by the ontology specialists accordingly. In addition, several complex queries were designed during the evaluation to leverage the relationships among the ontological classes.

As a result, results were obtained with pin-point elements and high accuracy. This evaluation focused on assessing the ontology's efficacy, particularly highlighting the hierarchical structure of the ontology knowledge and emphasizing how this structure enabled the ontology to effectively represent and confirm its effectiveness within the particular domain of knowledge it aims to address. In essence, it suggests that the hierarchical organization of the ontology played a crucial role in ensuring its accuracy and usefulness within the designated area of expertise.

Thus, the evaluation process emphasized the ontology's effectiveness and, in particular, its hierarchical knowledge structure and relations. It also aligned well with delineating and confirming its effectiveness within the specific knowledge domain.

For ontology validation, the study employed a comprehensive ontology evaluation process to validate its structural integrity and precise descriptive elements as follows. Initially, we invited three specialists in ontology development to conduct an in-depth analysis focused on ontology aspects such as hierarchy, relationships, and terminology consistency. This evaluation enhanced standards to eliminate complexity and enhance clarity. The results were systematically compiled and are presented in Table 2.

Apart from structural evaluation, applicability and effectiveness in real-world scenarios were also evaluated because this stage involved creating prototypes and hypothesis experiments in various contexts.

Table 2. Khmer stone castle ontology evaluation

Aspects	***Mean***	***Meaning (Degree)***
Scope determining	*4.65*	*High*
Classes /Concepts defining	*4.60*	*High*
Properties defining	*4.50*	*High*
Instances creation	*4.50*	*High*
Future development and application	*4.85*	*High*
Total	*4.62*	*High*

Hence, we designed real-world scenario evaluations to test ontology functionality and, in particular, its ability to facilitate information retrieval and integration in a dynamic environment. With the aim of practical capacity, we carefully selected the scenarios to stimulate potential real-life applications for credible adaptability and utility.

Thenceforth, results from these practical evaluations were both qualitative and quantitative and contributed insight into the ontology's performance under different conditions and contexts, as shown in Table 3. These dual approaches featured evaluation—combining specialists' evaluation and practical application— to ensure that the ontology accurately reflected theoretical concepts in the real world, facilitating practical and effective implementation of semantic search systems.

Table 3. Knowledge retrieval efficiency results (F-measure)

Retrieved	**Relevant**	**Irrelevant**	**Overall**
Semantic searching	Relevant meaning	Non-relevant meaning	Overall meaning
Able	62	0	70
Unable	0	12	-

3.1. The Khmer stone castle semantic search system

The semantic search significantly enhanced contextual search capabilities by intelligently interpreting the relationships between ontological schemas and the contextual meanings. Compared to general search systems, which rely predominantly on character comparison methods to sift through data or documents, this semantic search delves deeper into grasping the underlying concept and intention of a query. This is because the search system allows the query to transcend the limitations of basic keyword matching, which often misses the mark in accurately representing the user's intention. Consequently, the semantic search reduced the retrieval of cognate results which were irrelevant attributes or inaccurately manifested and authorized a more precise and contextually relevant search experience. These challenges were primarily raised due to the semantic gap between computer interpretation and human understanding [13]. We developed the system as a web-based application and considered a multitude of factors

to deliver meaningful search results, as well as easier accessibility. These included searching contexts, a word variation arrangement (corpus), and a comprehensive synonyms list. The semantic search also accommodates generalized and specialized search queries to cater to various informational needs, including those of experts, in concept matching, ensuring the results align closely with the user's intended meaning. Concept matching is crucial for professionals and researchers who require precise and relevant search results within specific domains of knowledge because they often work with complex concepts that may not be directly mentioned in the texts or documents they are searching through. Thus, they rely on the search system's ability to understand the context and the relationships between concepts to find the most relevant information.

Additionally, it was equipped to direct natural language queries, which provided a more intuitive and user-friendly search experience. This sophisticated approach endorsed relevant, richly contextualized, and highly accurate search results. Similarly, the software enabled the recognition of distinctions between the tangible cultural heritage sites so as to deliver the most relevant results. This semantic approach delivered these advantages based on a contextual and intelligent understanding of the meaning of the information developed for the sematic search system.

In this study, two primary characteristics of the semantic search system were developed for the Khmer stone castles in the Greater Mekong Subregion (GMS) to enhance capacity and accessibility as follows:

1) *Web Browser Programmability:* we designed the semantic search engine to be easily programmable via a web browser interface. This feature certifies that users can conveniently interact with the system without needing specialized software. With this flexibility and user-friendly attributes, the search facilitates customization and adaptation of the search engine to meet various user requirements. This web-based approach also improved system accessibility from different devices and platforms as well as enhancing utility and user-friendliness.
2) *Versatile Search Capabilities:* the system was equipped with robust search engine functionality to enable users to conduct searches using multiple approaches and to search by class properties. These functions are also able to add an enquiry option based on specific characteristics or categories defined in the ontology, such as location, era, architectural style, or material used. Additionally, the two search methodologies include both simple and advanced semantic searches, and the system also supports searches using the name of a specific Khmer stone castle or relevant keywords.

3.1.1. Aspects of the system's semantic search capabilities

The simple search function involved common information retrieval and was suitable for general queries, while the advanced semantic search function offered deeper, more complex, and more distinct data exploration, making it ideal for specialized information retrieval or detailed inquiries. To illustrate the system's capabilities and user interface, we have included a semantic search system prototype in Figure 3. The prototype provides a visual and functional representation of the system's operation, showcasing the practical application of the theoretical concepts underpinning this research. The system prototype incorporeally demonstrated how users can explore and access information about the Khmer stone castles in the GMS, which highlighted its value as a tool for researchers, historians, and enthusiasts interested in cultural heritage.

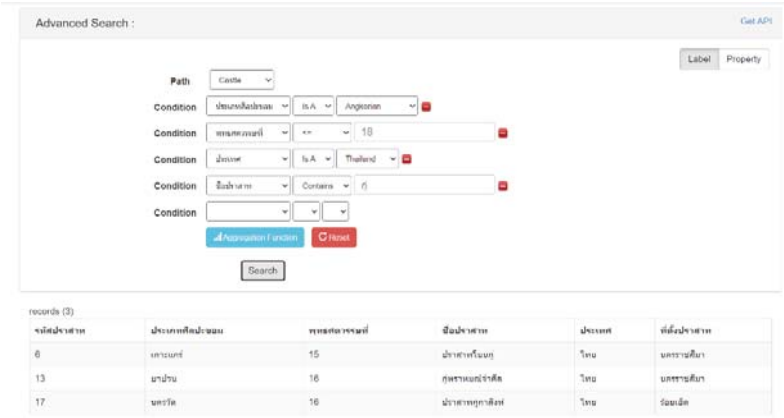

Figure 3. Prototype of a Khmer stone castle semantic search system.

For this research, we utilized an existing database containing information about Khmer stone castles, which is predominantly in the local language (Thai). Subsequently, we developed an ontology to establish a mapping with the database, enabling the creation of a semantic search system.

As a result, queries made through our system display information in the Thai language, consistent with the data stored in the database (we have made the detailed Khmer Stone Castle ontology created in this study available for users and can be accessed via the Internet at https://ischool.kku.ac.th/owl/index-en.html, as referenced in the body text preceding Figure 1).

3.2. Semantic search system performance evaluation

In this stage, an application-based ontology evaluation was conducted to assess ontology structure efficacy and evaluate information retrieval effectiveness through a semantic search prototype. An Ontology Application Management (OAM) framework was adopted to develop this semantic search system prototype, which provided versatile, reusable, and configurable templates ideal for rapid prototyping and hypothesis testing. This framework also included a Web API to be more sophisticated in application development. To measure the effectiveness of the ontology, the key information retrieval metrics were conducted in addition to precision, recall, and F-measure [14]. The evaluation involved calculating three critical metrics:

1) The precision value, which indicated the proportion of relevant documents retrieved;
2) The recall value, which represented the proportion of relevant retrieved documents;
3) The F-measure, which calculated a specific formula.
4) The performance analysis in the semantic search system yielded precision, recall, and F-measure values at 0.885, 0.756, and 0.815, respectively. These results provided valuable insights into the efficacy of the search system and highlighted areas for potential improvement.

Table 3 shows the advanced search performance evaluation results, explicitly focusing on the F-measure, a metric combining precision and recall. The data shows an average F-measure of 0.815 for the advanced search. This figure was particularly noteworthy because it indicates a high level of effectiveness in the semantic search system based on ontology knowledge. The F-measure was a balanced metric for considering the precision (the accuracy of the results returned) and recall (the system's ability to retrieve all relevant results). An F-measure of 0.815 suggested that the system not only retrieved a high percentage of relevant results (high recall) but also confirmed that these results were accurate and pertinent to the query (high precision). Thus, they were especially significant in the semantic search, suggesting that these elements carried significant weight in semantic search scenarios, where the ability to comprehend context and queries was paramount for a successful outcome.

The exceptional browsing efficiency highlighted by this F-measure indicated that the semantic search system was proficient at interpreting and processing complex queries in the domain of cultural heritage. This efficiency is critical for researchers and scholars who rely on precise and comprehensive search results to conduct their work effectively. The system's ability to interpret the queries accurately and retrieve highly relevant information was demonstrated in the successful application of the ontology knowledge base to enhance search capabilities. Generally, a high F-measure highlights the success of the ontology in bridging semantic gaps and improving the search experience by making it a valuable tool for exploring and researching the cultural heritage in the ontology.

4. Conclusions

In conclusion, this study focused on developing a semantic search system for the Khmer stone castles in the GMS countries, adhering to UNESCO's policies for preserving cultural heritage. According to these guidelines, compiling a list of tangible cultural heritage, encouraging research, and gathering related documents or evidence for effective safeguarding measures and educational purposes were crucial. Consequently, we proposed the creation of a database for Khmer stone castles featuring high-quality data verified by specialists for validation.

Following the organization of the data in the database, a systematic approach was employed to establish a comprehensive knowledge base for educational and research purposes. This entailed structuring the data coherently to facilitate easy access and utilization by educators, researchers, and other stakeholders interested in the domain covered by the database. Additionally, efforts were made to ensure that the knowledge base met the standards and requirements for its intended use, enhancing its value and applicability in the field. Regularly updating and interlinking data also effectively helps to disseminate knowledge when it is easily accessible, forming a key cornerstone in managing tangible cultural heritage.

The study results demonstrated the significant outcomes and high level of effectiveness of the semantic search system for accessing information about the Khmer stone castles in the Greater Mekong Subregion (GMS) countries. This system has the potential to act as a benchmark for other cultural information search systems and significantly improve information retrieval in specialized domains. Furthermore, this study also laid the groundwork for the creation of similar search systems in different areas of study to enhance methods for knowledge storage and retrieval. From a broader perspective, this research can open new paths, igniting further investigation of ontology for supporting the preservation of cultural heritage, particularly relevant in the context of

developing sustainable web-based information search systems that utilize semantic networks. The implications of this study were far-reaching, offering valuable insights and methodologies in the ongoing effort to conserve and make our rich cultural heritage accessible to everyone.

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References

[1] Changmai, P., et al. (2022). Ancient DNA from Protohistoric Period Cambodia indicates that South Asians admixed with local populations as early as 1st–3rd centuries CE. Scientific Reports, 12(1), 22507.
[2] O'Reilly, D. J. (2006). Early Civilizations of Southeast Asia. Rowman Altamira.
[3] Higham, C. (2001). The civilization of Angkor. Univ of California Press.
[4] Coe, M. D. (2020). The Khmer Empire. In The Oxford World History of Empire: Volume Two: The History of Empires (p. 430).
[5] Chansanam, W., Tuamsuk, K., Kwiecien, K., Ruangrajitpakorn, T., & Supnithi, T. (2015). Development of the belief culture ontology and its application: Case study of the Greater Mekong subregion. In Semantic Technology: 4th Joint International Conference, JIST 2014, Chiang Mai, Thailand, November 9-11, 2014. Revised Selected Papers (Vol. 4, pp. 297-310). Springer International Publishing.
[6] Uschold, M., & King, M. (1995). Towards a Methodology for Building Ontologies. In Proceedings of the IJCAI95's Workshop on Basic Ontological Issues in Knowledge Sharing (pp. 1-7). Montreal, QC, Canada.
[7] Manola, F., & Miller, E. (n.d.). RDF 1.1 Primer. Retrieved November 1, 2023, from https://www.w3.org/TR/rdf-primer/.
[8] V. Broughton, J. Hansson, B. Hjørland, and M.J. López-Huertas, "Knowledge Organization," Available online: https://issuu.com/bib.csinfo/docs/broughton__2005, accessed on 14 November 2023.
[9] M. Uschold and M. King, "Towards a Methodology for Building Ontologies," in Proceedings of the IJCAI95's WS on Basic Ontological Issues in Knowledge Sharing, Montreal, QC, Canada, 13 April 1995.
[10] N. F. Noy and D. L. McGuinness, "Ontology Development 101: A Guide to Creating Your First Ontology," 2001. [Online]. Available: https://protege.stanford.edu/publications/ontology_development/ontology101.pdf. Accessed on: November 20, 2023.
[11] Osaka University, "Hozo–Ontology Editor," Osaka University, Osaka, Japan, 2011.
[12] D. Garijo, "WIDOCO: A wizard for documenting ontologies" in Proceedings of the 16th International Semantic Web Conference (ISWC 2017), October 21-25, 2017, pp. 94-102, Springer.
[13] Buranarach, M., Supnithi, T., Thein, Y. M., Ruangrajitpakorn, T., Rattanasawad, T., Wongpatikaseree, K., Assawamakin, A. (2016). OAM: An Ontology Application Management Framework for Simplifying Ontology-based Semantic Web Application Development. International Journal of Software Engineering

and Knowledge Engineering, 26, 115–145.
[14] Belew, R. K. (2000). Finding out about: A cognitive perspective on search engine technology and the WWW. Cambridge University Press.

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Summary

The aim of this study was to develop a semantic search system for Khmer stone castles in the Greater Mekong Subregion (GMS), in alignment with UNESCO's cultural heritage preservation guidelines. The proposed database, curated with verified, high-

quality data, serves as a comprehensive knowledge base for educational and research purposes. The semantic search system demonstrated high effectiveness, showcasing its potential as a benchmark for cultural information retrieval. The study contributes to establishing similar systems in diverse domains, paving the way for ontology-driven approaches to support cultural heritage preservation and sustainable web-based information search systems. The far-reaching implications offer valuable insights for the conservation and accessibility of cultural heritage.

Riassunto

Questo studio mira a sviluppare un sistema di ricerca semantica per i castelli in pietra Khmer nella sottoregione del Grande Mekong (GMS), in linea con le linee guida per la conservazione del patrimonio culturale dell'UNESCO. Il database proposto, curato con dati verificati e di alta qualità, funge da base di conoscenza completa per scopi didattici e di ricerca. Il sistema di ricerca semantica ha dimostrato un'elevata efficacia, mostrando il suo potenziale come punto di riferimento per il recupero delle informazioni culturali. Lo studio contribuisce a stabilire sistemi simili in diversi domini, aprendo la strada ad approcci guidati dall'ontologia per supportare la conservazione del patrimonio culturale e sistemi sostenibili di ricerca di informazioni basati sul web. Le implicazioni di vasta portata offrono spunti preziosi per la conservazione e l'accessibilità del patrimonio culturale.