Arab American University- Palestine
Faculty of Graduate Studies

Towards a Precision-Oriented Multi-Lingual Semantics-Based Cultural Heritage Recommender System

By

Muhanad S. Altawil

Supervisor

Dr. Mohammed A. M. Maree

Co- Supervisor

Dr. Amjad Rattrout

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Muhanad Sameeh Altawil

This thesis was defended successfully on 23/5/2020 and approved by:

Committee members	Signature
1. Main Supervisor: Dr. Mohammed A. M. Maree	
2. Co-Supervisor Name: Dr. Amjad Rattrout	....
3. Internal Examiner Name: Dr. Muath Sabha	....
4. External Examiner Name: Dr. Labib Arafeh	....

Declaration

This is to declare that the thesis titled "**Towards A Precision-Oriented Multi-Lingual Semantics-Based Cultural Heritage Recommender System**" under the supervision of Dr. Mohammed Maree and Dr. Amjad Rattrout is my own work and does not contain any unacknowledged work or material previously published or written by another person, except where due reference is made in the text of the document.

Signature:

Muhanad Samih Altawil

Date:

Dedication

I dedicate my thesis work to my family for being my source of strength and inspiration. A special feeling of gratitude to my loving parents who gave me life after Allah, as well as my dear brothers and my dear sister, whose words of encouragement have led me to persevere.

I will always appreciate everything they have done to help me develop my skills, and for guiding and educating me.

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Thanks for all your encouragement

إهداء

أُهدي هذا البحث إلى..

أبي وأُمّي وأشقائي الذين لم يتوانوا عن دعمي ومساندتي في رحلة حياتي.

إلى من ساهم في بث السعادة والطاقة في قلبي وعقلي.

الحمد للهِ دوماً صاحب النعم والعطايا ... ربّ العالمين.

الشُّكر لمن هم أهلٌ له

الشكرُ دائماً لله الذي غرس في نفسي وهج الإيمان .. وفي عقلي نعمة التفكير .. وفي حياتي لذّة القراءة وحب العلم.

إنه صانعي الذي كوّر فيَ لهفة البحث والتدوين عن كل جميل... إنّه ربّي الذي منحني زاداً يغذّي عقلي برشد القول .. وحكمة الفعل .. وحصافة القرار... له الحمد الدائم .. والشكر المتواصل لربّي وخالقي وصانعي .. الذي وفّقني في إعداد هذا الموضوع .. عن بلاد حفاها وشرفها .. لتعمّ فائدتها على الناس....

شكراً في المبتدى والمنتهى لله رب العرش العظيم، ولعائلتي على إتاحة التفرغ لي لإعداد هذا البحث الذي لم تطرق أبوابه عن هذه البلاد من قبل.

Abstract

The cultural heritage sector and its associated tourism facilities have been affected notably by the advancement of the Internet, as well as the explosive growth of smartphones and other handheld devices. These days, visitors have access to reliable and trusted content related to cultural heritage sites world-wide. They can access this information either using the Internet (via Web interfaces) or by using their handheld devices. Considering the latter approach, a user can search for any desired site, and details that pertain to it will be presented in a timely fashion and neat interface. However, conventional cultural heritage information systems lack the ability to adapt their behavior to the preferences, needs, interests and other features that are required by users (be they single tourists or tourism groups). In this research work, we address the issue of designing an effective multi-lingual semantics-based mobile recommender system about Palestine's cultural heritage. We facilitated users' access to cultural heritage content by providing them with multiple search functionalities. In this context, a user can search for cultural heritage sites or topics via a dedicated interface; wherein the system takes a given query as input and retrieves all relevant cultural heritage documents based on their semantic similarity. Accordingly, users can express their information needs using keywords (a.k.a. tags) or sentence-like queries to describe their information needs. The proposed system processes users' queries by utilizing natural language processing techniques, multi-lingual ontologies and other term relatedness measures. A second option is to search by using current location (to retrieve historical places and events associated with the place where the visitor is located), considering network availability. A third option allows users to capture and submit images as input and the system accordingly retrieves all relevant results based on their content similarity, such as texts or objects detected and recognized in the given images, where users can then share the returned result with their friends. Moreover, the proposed

mobile-based application is aimed to adapt itself to the user preferences and information needs; for personalizing their experience on one hand, and offering more effective and efficient interaction on the other. In this context, the system acquires user queries and automatically and gradually deliver its output to meet the user's information needs and preferences based on her/his logging information. To evaluate the quality of the utilized techniques, we have developed a prototype of the proposed mobile-based application and tested it using Android devices and a manually-constructed ontology (henceforth named as Holy-Land Ontology) that we have enriched with links to the Art & Architecture Thesaurus (AAT) and DBpedia semantic thesaurus about cultural heritage information. When we compare our system with other systems in this field, findings demonstrated that our system provides additional search features and functionalities to users. The implementation of machine learning techniques to extract and recognize objects from images has also helped users to better understand the content of the images that they captured. In addition, our constructed ontology is the first one that address cultural heritage in the holy-land region.

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List of Abbreviations

AAT – Art & Architecture Thesaurus

CH – Cultural Heritage

CHIR – Cultural Heritage Information Retrieval

CNN- Convolutional Neural Network

IR - Information Retrieval

NLP – Natural Language Processing

QR - Query Reformulation

OWL – Web Ontology Language

QBE – Query-By-Example

R-CNN- Regions Convolutional Neural Network

RDF – Resource Description Framework

RMSE - Root Mean Square Error

CHAPTER ONE- INTRODUCTION

In this chapter, we present an introduction to our research work in the context of the cultural heritage domain. First, in section 1.1, we provide a background about our research field and discuss the motivations behind developing our proposed system. Then, in section 1.2, we present the problem statement about existing cultural heritage systems. After that, in section 1.3, we identify and discuss the research questions and the research steps that we have implemented during our research work. In section 1.4, we highlight our contributions in the cultural heritage field, and in Section 1.5, we provide an overview about the scope of our research project. In section 1.6, we present our publications in the domain, and finally, in section 1.7, we present the organization of the thesis.

1.1 Background and Motivations

Over the past few years, greater attention has been given to the cultural heritage domain worldwide [1-3] and in Palestine in particular [4-7]. The interest in this domain has become a priority for countries to increase the public awareness about the importance of preserving and promoting cultural heritage content [8, 9]. On the other hand, many sources of information about relics, historical events, old buildings (ancient citadels, mosques, churches, old cities etc.) and other cultural heritage sites are the targets of tourists all over the world. They are continuously looking for sources of cultural heritage information to be referred to as a reference to enrich their knowledge about existing cultural heritage locations and topics, prior or while visiting a certain heritage location. Accordingly, there is an ongoing demand for cultural heritage applications that facilitate users' access to cultural heritage information [10-17]. To cope with this demand, many systems have been proposed to assist users plan their travels and find cultural heritage information that best match their information needs [8, 18-24]. However, conventional cultural heritage information systems still lack the ability to adaptively provide the right cultural heritage content that precisely matches the preferences, tasks, interests and other features of individual tourists and tourism groups. Additionally, less attention has been paid to the issue of exploiting and offering multiple means of communication between users and applications in this domain. In other words, users are often provided with keyword or sentence-like querying options; ignoring the semantic aspects that are latent in the content of cultural heritage documents, as well as their corresponding queries. In this research, our objective is to tackle the issue of designing and developing a precision-oriented multi-lingual semantics-based cultural heritage recommender system. We aim to better facilitate users' access to cultural heritage information by providing them with multiple search functionalities and features. In this context, using the proposed system, a user can search for cultural heritage sites or topics via a dedicated interface; wherein the system takes a given query as input and retrieves all relevant cultural heritage documents based on their semantic similarity. Accordingly, users can express their information needs using multi-lingual keywords (a.k.a. tags) or sentence-like queries to describe their information needs. The system supports two additional search functionalities; these are 1) search by location and 2) search by example images. Using these options, a user can search by using his/her current location (to retrieve historical places and events associated with the place where the visitor is located in), considering network availability. On the other hand, the query-by-image-example option allows users, when visiting any place, to take pictures of what they have been inspired by and upload those pictures online to share their experiences with their friends, enabling them to analyze these pictures in terms of their content, in addition to their captions (textual descriptions that are associated with each picture and other contextually-relevant information). Moreover, the proposed application is aimed to adaptively correspond to users' preferences and information needs; in an attempt to personalize their usage context and experience with the system. As such, the system is planned to be developed in a way that identifies and automatically responds to users based on their usage context and progressively tune its output to meet the information needs of users and their preferences.

1.2 Research Problem

As we have presented in the previous section, many systems have been proposed to assist users plan their travels and find cultural heritage information that best match their information needs [8, 11, 20, 25-27]. However, conventional cultural heritage information systems still lack the ability to adaptively provide the right cultural heritage information that precisely matches the preferences, tasks, interests and other features of individual tourists and tourism groups. Additionally, fewer attentions have been given to exploiting multiple means of interaction between users and relevant systems in the domain. In other words, users are often provided with either text-based or query-by-example (image or label) based search interfaces, but not both.

This research project addresses the issue of developing a precision-oriented multi-lingual and semantics-based cultural heritage recommender system in the context of the cultural heritage domain. We aim to better facilitate users' access to cultural heritage information by providing them with multiple search functionalities. In this context, a user can express his/her information needs about a certain cultural heritage site or topic via a query-by-example interface; wherein the system takes a given image as input and retrieves all relevant images based on their content similarity (using the metadata and low-level features of the compared images). In the second approach, users can express their cultural heritage information needs using keywords (a.k.a. tags).

In this context, the produced system will process users' queries by using Natural Language Processing Techniques (NLP), multi-lingual ontologies and other statistical-based concept-relatedness measures. Additionally, users can employ the search-by-location feature to search for nearby cultural heritage locations. Moreover, the proposed system is aimed to adapt itself to meet the preferences and needs of its users based on their usage context; in an attempt to achieve a more effective as well as efficient interaction with users.

1.3 Research Question and Methodology

In this section, we define and discuss the main components that are used as the building blocks for developing our proposed system. These are the constructed ontology; supported in multiple languages, and the mobile-based recommender system; supported with multiple search functionalities and a hybrid filtering component. Next, we discuss the main research questions that we attempt to answer, in addition to presenting the exploited research methodology for addressing these questions.

1.3.1 Ontology

The term *ontology* has become very popular in many research domains including the cultural heritage domain. Ontologies are basically used to provide a semantic framework for encoding and organizing knowledge about the domain of interest. According to Greg Linden and et. al, [28-31] Ontologies include hierarchical structuring of knowledge about domain concepts, instances, and the relations that link them by categorizing and organizing them in a graph-like structure and using specific syntax such as Web Ontology Language (OWL) and Resource Description Framework (RDF). Various ontologies are employed to describe a content that pertains specific domain knowledge through understanding and explicitly defining the attributes of primitive types (concepts, relations, functions and their axioms). Despite the fact that ontologies provide precise explicit knowledge that is agreed upon and normally shared across people and machines, there are some drawbacks in existing ontologies. Among these drawbacks are the semantic heterogeneity and knowledge incompleteness. The main reasons behind the first drawback are due to the way these ontologies are formulated and constructed by different groups of expertise and individuals. When users have different perspectives about the domain of interest, several heterogeneous ontologies will be produced each of which has a common, but also different or sometimes contradictory semantic definitions. In addition, ontologies can be constructed using different syntaxes as well as different tools resulting in inconsistency among ontologies that attempt to capture knowledge on the same domain. As far as the second drawback is concerned, it is practically impossible to have a single ontology that accurately captures knowledge about all domains. Therefore, even with very heavy-weight ontologies, we still find a lot of entities that are either incorrectly definite in the ontology or are not recognized in its structure.

1.3.2 Mobile Recommender System

The design of mobile-based recommender application is largely based on the fact that we need to retrieve information that are more related and assumed to be relevant to users; aiming to effectively minimize the amount of produced information and reducing the amount the displayed details on mobile screens, particularly when compared to the amount of information that can be retrieved using a standard web interface. The advantage of mobile-based systems in this context is that they can be used in any place as long as users can access the internet. This feature can greatly impact users' experience as it allows them to collect information about any cultural heritage location or other related details during their travel; allowing providing ad-hoc results and enhancing the recommendations on the spot. Another aspect that is important about mobile-based recommender systems is the possibility of utilizing the GPS which has become a core component of recent smart devices. Using this features, users can locate their current location and submit this data to retrieve cultural heritage related information which is in locations that are nearby the user's location. In addition to these features, mobile devices are equipped with cameras wherein users can capture pictures that can be then used to retrieve information on subjects related to the content of those images; whether by extracting the text or objects in it and being able to share that with friends. We would like to point out that the system will be interactive, and able to retrieve additional relevant information depending on image contents. In particular, we're going to build a model for recognizing images on android devices using machine language tool kit that uses a three-ways label detection, object recognition, and face detection algorithms. We used a Regional Convolutional Neural Network (R-CNN) for objects recognition. As we know object detection and recognition has been a significant topic in computer vision and deep learning for developing many modeling techniques used in this field such as, R-CNN which was fundamentally used for object detection at the time of its conception, we implemented ML Kit to recognize text that used more than 103 different languages in their native scripts. In addition, Romanized text can be recognized for Arabic, English, French, Hebrew, Greek, etc. We have equipped it with Machine Learning (ML) algorithms that take images captured by the camera as input and extracts relevant information from the images to produce tags and other relevant content-based features as output. We believe that utilizing ML techniques in our proposed application offers users with an additional feature that is important in the context of our domain, as well as other important domains that have utilized the same techniques such as computer vision [32-34], text recognition [35-37], object detection and tracking [36] and natural language processing [38, 39]. The incorporation of such techniques has proved to outperform conventional computational and statistical functions such as those proposed in [40-44].

1.3.3 Hybrid Recommendation Approach

By utilizing hybrid recommendation techniques – that combine several recommendation criteria – we are able to provide users with results that tend to satisfy their information needs more effectively than conventional recommendation methods. When hybrid recommendation applications are compared to collaborative or content-based recommender applications alone, the accuracy of the results returned by the hybrid approaches is higher. This is because there is no information about domain adjuncts in collaborative filtering and about people's preferences in the content-based applications. In our work, we suggest a combined method of precision evaluation, in which collaborative filtering techniques are combined with content-based filtering approaches. Although there are a number of hybrid recommendation systems already in place, our approach is distinctive in classifying content and context information into a standardized model. In our proposed mobile-based recommender application there are five parameters for content recommendation that exist. These are: content-based - users' preferences - cosine results - previous searches, and location-based information. More details on each of these parameters are provided in the evaluation chapter.

Considering the research questions that we are trying to address in this research work, we mainly attempt to investigate and answer the following questions:

a) What are the possible features and functions that can be utilized to facilitate users' access to cultural heritage content?

b) How to combine and integrate multiple components (ontology, mobile recommendation, and hybrid filtering techniques) within a unique mobile-based cultural heritage recommendation scenario?

To answer the above mentioned questions, we follow the Design Science Research Methodology proposed in [45]. In this context, we namely carry out the following main research tasks:

1) Assess the research problem and identify its relevance
2) Delineate the research goals and motivations
3) Design a prototype of the proposed solution
4) Experimentally evaluate the developed prototype
5) Measure the effectiveness of the proposed solution

1.4 Contributions

In this section, we present the main contributions of our research work as follows:

- Providing users with a multi-lingual semantically-enhanced and contextually-relevant cultural heritage system that matches their information needs, preferences, and interests.
- Coupling semantics-based and concept-relatedness based information processing and retrieval techniques to facilitate users' access to cultural heritage information.
- Ranking results for user queries based on their relevance to the hidden semantic dimensions encoded in users' queries as well as in the content of the cultural heritage documents.

- Offering additional search features (search location and search by example images) to enrich users' interaction experience with the system and enable them acquire more information about cultural heritage content using a variety of methods.

1.5 Research Scope

This research project addresses the issue of designing a precision-oriented multi-lingual and multi-criteria semantics-based cultural heritage system. As tourists face problems to gain information about their favorite places or to search for nearby places, our proposed cultural heritage recommender system will tackle these problems by providing high precision ratio when answering tourist's queries. Furthermore, it will adaptively recommend cultural heritage information that best match his/her information needs and preferences.

To build the system, several text-based, as well as content-based matching algorithms will be employed. In this context, the system will analyze users' queries (either submitted as textual queries, query examples in the form of images, or location-based queries) and provide users with the most relevant results to their initial information needs.

Experimental instantiation of the proposed system will be carried out to validate our proposal. This validation will be accomplished by using a dataset of cultural heritage documents accompanied with a ground-truth about the documents and their relevance judgments. Users under three different categories (cultural heritage specialists, IT experts, and ordinary users) will be involved in the evaluation phase.

1.6 Publications

We would like to point out that due to time limitations, the large volume of cultural heritage data across the various geographical areas of Palestine, and more importantly the absence of a dataset that includes all cultural heritage information about Palestine, we have invested much effort to construct an ontology about the cultural heritage of Palestine and enriched it by data from global datasets Art & Architecture Thesaurus (AAT) and UNISCO. Then, we were able to obtain preliminary results that were tested using the prototype of the proposed system. The developed prototype was evaluated using different categories of users as we will demonstrate in this thesis. We have prepared the results and are now in the process of submitting them to the ACM Journal on Computing and Cultural Heritage (JOCCH). However, we would like to also point out that we were able to publish and present part of the results at one of the relevant conferences in the field of cultural heritage; the 6th HIS International Conference on Cultural Heritage, in Paris, in 2019.

1.7 Thesis Structure and Organization

The structure of this thesis is organized as follows. First, in chapter 2, we present our literature review and introduce a comparative analysis of existing cultural heritage systems. A general overview of the main components of our proposed system is presented in chapter 3. We introduce a detailed description of the techniques and methods that we utilize in the proposed system in chapter 4. Chapter 5 presents the conducted experimental evaluation of the effectiveness of the proposed system. In this chapter, we also compare between the result produced by our system and other similar system that used the same evaluation criteria and methodology. Finally, in chapter 6, we discuss our conclusions and outline the future extensions of our research work.

CHAPTER TWO- LITERATURE REVIEW

In this chapter, we review the literature through exploring a number of systems that are relevant to our proposed cultural heritage system. First, we present a background about cultural heritage systems. Then, we discuss the features of existing cultural heritage systems and approaches. We first start with exploring conventional cultural heritage approaches, and then we present semantically-enhanced cultural heritage approaches. We also provide a comparative analysis section wherein we compare between the features of each of the explored systems in this domain.

2.1 Background

The term culture is traditionally associated with the environment, materials and objects used and created by the population in a particular area [46]. Culture is also linked to knowledge and custom conventions used and maintained over the years [25, 47-50]. Heritage, on the other hand, creates a sense of identity where people feel their belongingness to the location, memories, sites, goods, and conventions that they live within and use as part of their daily life; with an aim of developing, preserving as well as sustaining the identities of locals across generations [51]. The main goal of our research in this context is to develop a platform that offers multiple services and functionalities that aim at enhancing users' personalized access to digital cultural heritage content. This platform comprises integrated cultural heritage ontology, multiple techniques and algorithms that are employed to enhance user's access to relevant Cultural Heritage (CH) content, and a mobile-based recommendation application. Semantic techniques in this context can be employed to enable explicit and commonly shared representation of domain knowledge, which can be communicated and deployed to serve as a central hub that captures knowledge about all domain primitives, and can be interoperability across multiple application domains. It is important to point out that the unstructured and scattered nature of cultural heritage information is challenging to be described in one single common ontology that may comprise the properties of objects stored anywhere in the world. Therefore, utilizing ontological approaches is not similar to the conventional approaches that are based on index cards, schema-depended indexers, or semi-structured metadata items, since the aim in this context is to override the implicit "level" schema details and be able to discover and cover the background knowledge and the richness of different information elements without any structure or common schema based centralization. By using and developing special ontology and semantic technology, any user will be able to search smoothly for Palestinian cultural heritage data, as if he/she has access to a large library of information, and intelligent user agents can process and attempt to understand the user's submitted query to support different and appropriate results using a variety of interaction mechanisms.

By conducting the literature review, and to the best of our knowledge, we couldn’t find multi-lingual cultural heritage ontologies locally for Palestine, or even globally-accessible ones. Due to this issue, and as part of our research contributions in this domain, we have constructed an integrated ontology for Palestine’s cultural heritage; laying the foundation for developing further semantic resources in this domain and highlighting the importance of cultural heritage for bridging the semantic gap between user queries and their corresponding cultural heritage content. Much effort has been invested in this task in an attempt to provide the appropriate methods which are considered as a prerequisite for putting things in context and understanding the cultural heritage content. In addition to the constructed ontology, we implement different techniques to support cultural heritage recommendations systems from user preferences within a range of factors, including multi-lingual query support, multi-search options support in the user interface, and textual, image and location results retrieval.

2.2 Existing Cultural Heritage Systems and Approaches

Recently, researchers have proposed several recommender systems and applications that aim at guiding tourists and providing them with cultural heritage information. Some of these approaches are established solely based on the users' preferences [52-54]. On the other hand, other approaches such as the one proposed by Kunyanuth and Bundit and others [13, 25, 55, 56] apply ontology and hybrid recommendation techniques to develop an effective heritage-tourism recommender system that helps tourists search and make decisions and plan their trips. The recommendation process is separated into two parts: analyzing the current position and examining the suitability of information for users by using their preference, location and hybrid filtering recommendation techniques. In a similar line of research, Maarten et. al. [57, 58] proposed recommending location-based cultural heritage information based on a user's visiting history in a geographical region. The results showed that recommendations that used co-occurrence techniques are more precise and efficient than recommendations based on the earlier travel probability. In addition, the mobile recommender system has been equipped with multiple algorithms and feature-based techniques that match a user profile and search context incorporating user's personal preferences [23, 43]. Similarly, a location service and an event-based mobile recommender system were introduced to personalized tourist information access [59, 60]. Another system is MoreTourism [55]; which is an Android-based mobile recommender system that makes use of various multimedia document types such as, video and image elements in addition to other available features to assist users accessing the desired cultural heritage information. EnoSigTur [61] is another system that is developed for Android platforms for recommending places, description of place of interest and route aiding for trips. Additional applications are mobile-based tourist guides that allow tourists to find cultural heritage locations and services based on personalized recommendations. The systems proposed in [12, 27, 48, 62, 63] are aimed to provides relevant information to tourists based on accumulating their experiences. In [19, 64], the authors address problems related to personalizing the users' experience by developing a framework for tourism recommendation systems. Researchers in [19, 64, 65] have used semantic resources to enhance the precision of mobile search engines based on keywords by using a lightweight mobile ontology. Experimental results show that the suggested module provides more precise search results and a better user experience compared to the conventional techniques. In [57, 66, 67], another similar semantic-based recommender system is proposed. In [66], Pierpaolo et al, presented a mobile-based recommender system that aims at supporting tourists as well as teachers in the cultural heritage domain based on user-centered and collaborative approaches to promote cultural heritage knowledge through the utilization of a set of metadata that enables resource contextualization in the culture of a territory. In addition, the system was combined with genetic algorithms and fuzzy logic techniques to carry out the matching task considering user profiles (based on their personal preferences) to retrieve their corresponding cultural heritage information [37, 55]. Similarly, an event-based system, in addition to a location-based service have been developed and deployed within a mobile environment to act the as a personalized recommender that provides tourists with the required cultural heritage information [20, 68]. The proposed recommendation application used collaborative-based filtering in the case of Macedonia which was implemented to be capable of generating a personalized list of favorable and tailor-made choices [69, 70]. In [63], the authors have developed an application for integrating cultural heritage data based on semantic web technologies. In their application's context, the authors developed the Gothenburg City Museum through the exploitation of PROTON and CIDOC-CRM (is an object oriented ontology developed by the international council of museums committee) ontologies in addition to enrichments obtained using the GeoNames, Catalogue of Life (CoL), DBpedia, and Uniprot knowledge resources. A similar system was proposed in [47, 50, 64] by Lais Barbudo Carrasco which introduced a framework for finding ontological mapping entities from cultural heritage metadata. The developed ontology in this context was developed to achieve interoperability across sundry digital cultural heritage repositories. Also, in [65], Erika S. and Flávio S. have presented an architecture that is based on the Museum of Contemporary Art at the University of São Paulo (MAC-USP) wherein cultural heritage data is represented using RDF syntax in an attempt to build a commonly shared language for capturing relationships about cultural heritage elements. In the same context, Giannis Skevakis et al., have proposed Linked Data Cloud [50, 71, 72] which was developed to present the architecture for transition of the Natural History Museum repositories. Using the proposed system, cultural heritage information was gathered from six different Natural History Museums around Europe. Similarly, Dmitry Mouromtsev et al. developed the Russian Linked Culture Cloud [72] for presenting a method for providing access to open linked data that is acquired from the Russian Museum through the exploitation of CIDOC-CRM ontology and relating the extracted data to DBpedia and the British Museum.

By reviewing the features of the abovementioned systems and exploring their features and services, we can see that the techniques proposed in these systems depend on specific factors for presenting search results to users, either when querying or when providing preferences. Accordingly, inspired by these systems, we have integrated these different factors such as user preferences, previous multi search functions and querying options such as, visited sites, most relevant search results within resources, and using a special ontology for Palestine cultural heritage with enrichments obtained from global ontologies such as CIDOC and DBpedia to improve the results presented to users of the Holy-Land cultural heritage system. The current version of the developed system is a pilot phase that can be further extended to be a global system that provides access to cultural heritage content world-wide. In the next table, we summarize the features and characteristics of the explored system using a number of criterions including: Supported ontology, Recommendation approach, targeted platform, Multi-language support, Semantic search support, Testing and Evaluation method, and Additional Supported features.

Table 1. Main features that distinguish the studied cultural heritage systems

No.	Name	Supported Ontology	Recommendation approach	Targeted Platform	Multi-Lingual	Semantic Search Support	Testing and Evaluation method	key features of application
1	Bangkok-Cultural Heritage-Tourism Thailand.	Design ontology for Thailand.	Collaborative filtering recommendation	Android-based mobile application.	No	Supported	Black box Testing, Questionnaires were used to assess in this phase with experts and users.	Recommendation depend on similarity and recommendation dataset
2	Museum of the Person (OntoMP)	CIDOC-CRM, FOAF and DBpedia.	Content based filtering recommendation techniques.	Web App./ Apache Jena TDB.	No	Supported	Some queries were built to test if the system could get the answers required.	Integration between the three ontologies. for Brazil, Portugal, USA, and Canada
3	Russian Linked Culture Cloud	CIDOC-CRM, DBpedia and British Museum thesauri.	Interactive with users preferences	Android – mobile app. And Web app.	Two languages	Supported	Used manually constructed evaluation (comparison of the general and original dataset metrics)	Information presented depends on user preferences and location based.
4	European Cultural Heritage	CIDOC-CRM, EU FP7 ARIADNE, CCCS, AAT, EUROVOC, UNESCO, LC. (venue Ontology)	Content based filtering	Mobile application	Multi languages	Supported	Used manually constructed evaluation (As a baseline we compare to the mean year predictor)	Mapping NG(National Gallery) data to the CIDOC-CRM
5	MapMobyRek Cultural heritage	Database attraction	Collaborative filters, knowledge-based and content based	Mobile application	Multi languages	Not supported	Used manually constructed evaluation (Comparison the result between list-based and map-based)	Map-based interfaces. The recommendation session begins when the user asks for a product proposal and ends when the user chooses a product or

								when they leave the system
6	PSiS(Personalized Sightseeing Tours Recommendation System)	Database attraction	content based	Mobile application	No	Not supported	No	all the recommendation aspects are on the server that related with city/region
7	Macedonia Cultural heritage	Design ontology.	content based	Mobile application	No	Supported	Used manually constructed evaluation (comparison of the general and original dataset)	No
8	Rijksmuseum Cultural heritage	Design ontology.	content based	Mobile /Web application	No	Supported	Some queries were built to test if the system could get the answers required.	Used machine learning to analysis the images
9	Swedish Cultural heritage	Design Cultural-ON ontology.	content based	Mobile application	Multi-language	Supported	Used manually constructed evaluation (Comparison of the general and original dataset)	Recommendation depend on similarity and location based
10	Holy-Land cultural heritage recommender system	Design Holy-Land ontology. AAT and DBpedia	Hybrid approaches	Mobile app Application	Multi-language	Supported	Black box Testing, Questionnaires were used to assess in this phase with experts and users.	Recommendation depends on similarity. Used machine learning to recognition images. Provides information by using three ways.

2.2.1 Conventional Cultural Heritage

The conventional definition of heritage as tangible and intangible inheritance has shifted into a more dynamic perception that sees heritage as "*a present-centered cultural practice and an instrument of cultural power*" as stated in [73]. This definition has been actually formulated in light of the definition of Roussin who defined heritage as: "*the capacity of a site to convey, embody, or stimulate a relation or reaction to the past is part of the fundamental nature and meaning of heritage objects*" [74].

With the increasing political and cultural implications of heritage in the modem world, academic literature views heritage increasingly not only as a space of consensus and accord, but also as an arena of conflict and contention [75]. Tunbridge and Ashworth [76] take heritage to a further level by emphasizing it as a selective process in which "*an inheritance from an imagined past is selected and passed on to an imagined future*". This selectivity is designed, according to [75], to construct collective social memory. What is selected and presented as heritage reflects specific people - their history, cultures, historic as well as contemporary contexts, and ways of life - while it marginalizes others. Therefore, meanings that are constructed for heritage, and generated from it, are mostly embedded in discourses of power.

The above arguments about heritage focus on material of the past not only as assets, but also as a dynamic field of interaction between this material and its complex context. In this sense, issues that are inextricably related to people's lives, such as cultural identity, empowerment and development, become part of the way material of the past is approached. It is through these issues that local communities interact with material of the past to create `heritage'. This interaction is at the center of the meaning-making process of archaeological sites.

2.2.2 Semantically-Enhanced Cultural Heritage Approaches

The utilization of various semantics-based approaches for representing cultural heritage information aim at providing users (tourists in our context) with services that can assist them find cultural heritage information that is semantically-relevant to their initial information needs. Additionally, using such approaches, our aim is to enhance users' experience with the developed application as they can learn about users' interactions, preferences and usage context to further improve the quality of the returned results. Considering these important goals and from a standpoint of a computer science researcher, semantic resources are referred to and utilized as a source of semantics-based information that are normally organized in hierarchical structures wherein concepts, their instances, and the relations that relate them are explicitly defined to identify and describe knowledge about the domain of interest (cultural heritage in our context). As such, and unlike schema-depend approaches, in order to respond to user submitted queries, query languages need not only to understand the syntax of the submitted query, but also its semantic descriptors that can be used to enrich the set of the retrieved results with additionally semantically-relevant items. To date, understanding queries syntax is not the real challenge compared to understand the semantics (meaning) of a given query. This is indeed a challenging task due to the heterogeneity in the content of cultural heritage documents on the one hand, and that is in the terms used by queries to express their information needs [9, 13, 65, 67, 77-80].

In our research work, our goal is to first construct manually-crafted semantic resources in an attempt to identify semantic relations that can be utilized as part of content-based recommendations; which can be accordingly employed to enhance the semantically-improve the quality of the produced recommendations and be further reused during similar recommendation scenarios. Different methods have been used in this context in an attempt to enhance the semantics-level recommendations in the cultural heritage domain. For instance, in the work proposed by Rijksmuseum in [81], users were asked to fill out a questionnaire before starting a session. The questionnaire focused on the following main aspects: the age of each user, whether they have used similar recommendation applications before, their experience context, what they expect from the developed system, and the reasons behind using the proposed application. And then allow users to rate the first set of recommended results. The proposed system produced recommendations in the form of semantically related cultural heritage concepts through the incorporation of semantic relations; allowing users to evaluate the returned results and to rate them according to their relevance to their information needs. Users were given an option to click on "Why recommended" button and submit their feedback to describe whether they found the given recommendation interesting and relevant or not using a 5-degree rating scale. The results of the developed system demonstrated that using terms that are relevant to the domain of interest have been found more useful for content-based recommendations against general terms.

2.3 Summary

In this chapter, we have introduced the term cultural heritage and highlighted its importance across multiple aspects. We have also reviewed a number of existing cultural heritage systems; highlighting their main strengths and drawbacks. We have summarized the explored systems and provided a comparison among these systems using a set of comparison criterions. In addition, we have explored the aspects of conventional cultural heritage and the main issues that are concerned with this domain. We have also discussed the importance of incorporating semantic resources in the context of recommending cultural heritage content. In this context, we have explored a number of features that are important to assist users finding more relevant results based on the exploitation of cultural heritage ontologies.

CHAPTER THREE - SYSTEM OVERVIEW

In this chapter, we introduce our proposed mobile-based recommendation approach in the cultural heritage field. First, we present an overall overview of the system's architecture from a three-layer based perspective in section 3.1. Then, we discuss the theoretical basics and formally formulate our problem domain in section 3.2. Next, we describe the various weighting parameters that are included in the proposed hybrid recommendation module in section 3.3. We discuss the conclusion and summarize this chapter in section 3.4.

3.1 Overall System's Architecture

In this section, we present an overall architecture of the proposed recommendation mobile-based system in the cultural heritage filed, where we exploit semantic matching techniques, with multi-lingual and additional search functionalities including searching by location, searching using example images and traditional search by user's natural languages. In particular, we describe the data source; using Holy-Land ontology mapped with CIDOC-CRM ontology that is described using Resource Description Framework (RDF) syntax. The exploited ontology is also integrated with DBpedia to expand its coverage and enrich it with additional relevant concepts in the cultural heritage area. We also present the Back-End component; where the resulting data is propagated through the SPARQL 1.1 endpoint, using additional backend platform services that are important for visualization, search, navigation, and data providing services including: data acquisition, transformation, algorithms to retrieve information: Content-based, multilingual, semantics-based, enrichment. The Front-End component is represented in the form of a mobile-based application interface that is created to facilitate users' interaction; allowing them to search with keywords in natural language or upload images to retrieve the results that are similar to the submitted image.

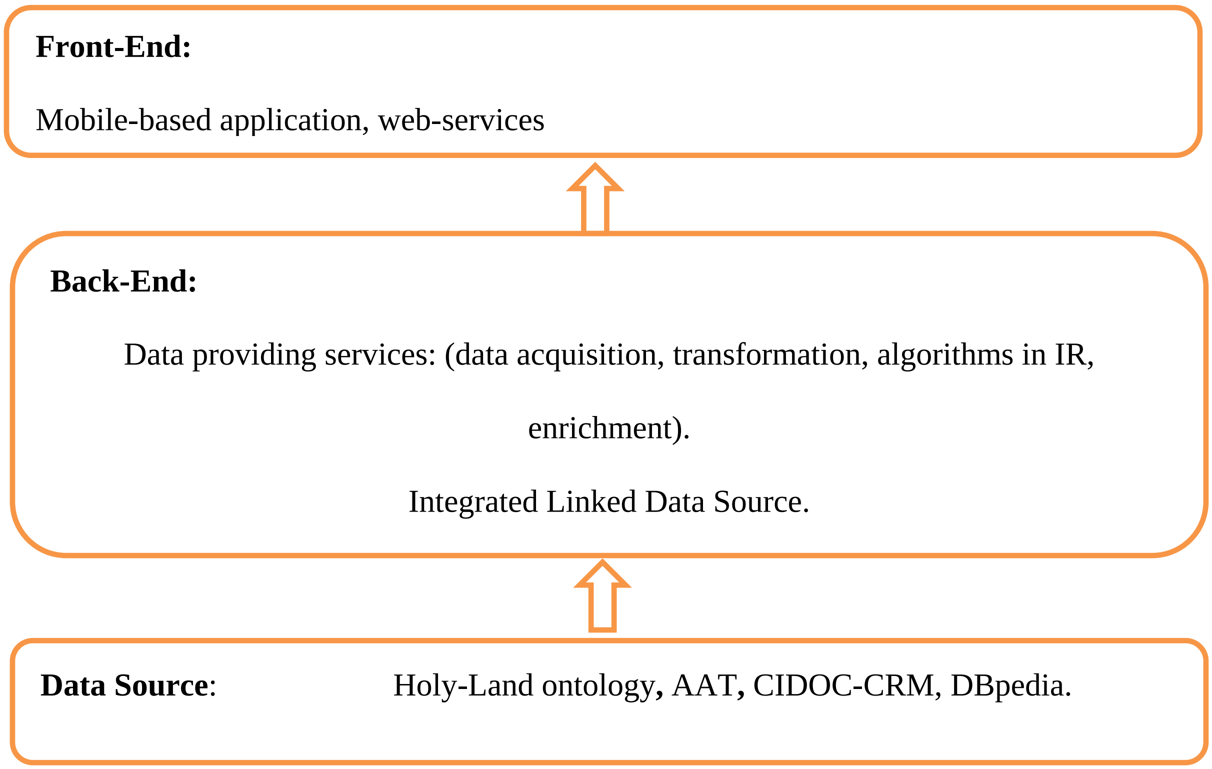


Figure 1. Three-layer system architecture

As we discussed in the previous section, we aim to construct ontology for Palestine's cultural heritage in order to be exploited to precisely enable user's access semantically-relevant cultural heritage content. As depicted in Figure 2, the proposed system comprises different modules that are all created to provide users with multiple search functionalities. In this context, and among these features, a user can search for cultural heritage sites or topics via a dedicated interface; wherein the system takes a given query as input and retrieves all relevant cultural heritage documents based on their semantic similarity. Accordingly, users can express their information needs using keywords (a.k.a. tags) or sentence-like queries to describe their information needs. The application processes user's queries by utilizing natural language processing techniques, multi-lingual ontologies (Arabic, English, Hebrew, and French) and accordingly retrieves the set of relevant cultural heritage information as shown in Figure 2. A second option that is offered for users is to search by using current location (to retrieve all historical places and events associated with the near places where the visitor is located), considering network availability. In this context, location information based cultural heritage documents are retrieved. Additionally, we provide user with a third option that allows users, when visiting any place, to take pictures of what they have been inspired by and upload those pictures online to analyze these pictures to take their captions (textual descriptions that are associated with each picture and other contextually-relevant information) and allow users to share their experiences with their friends.

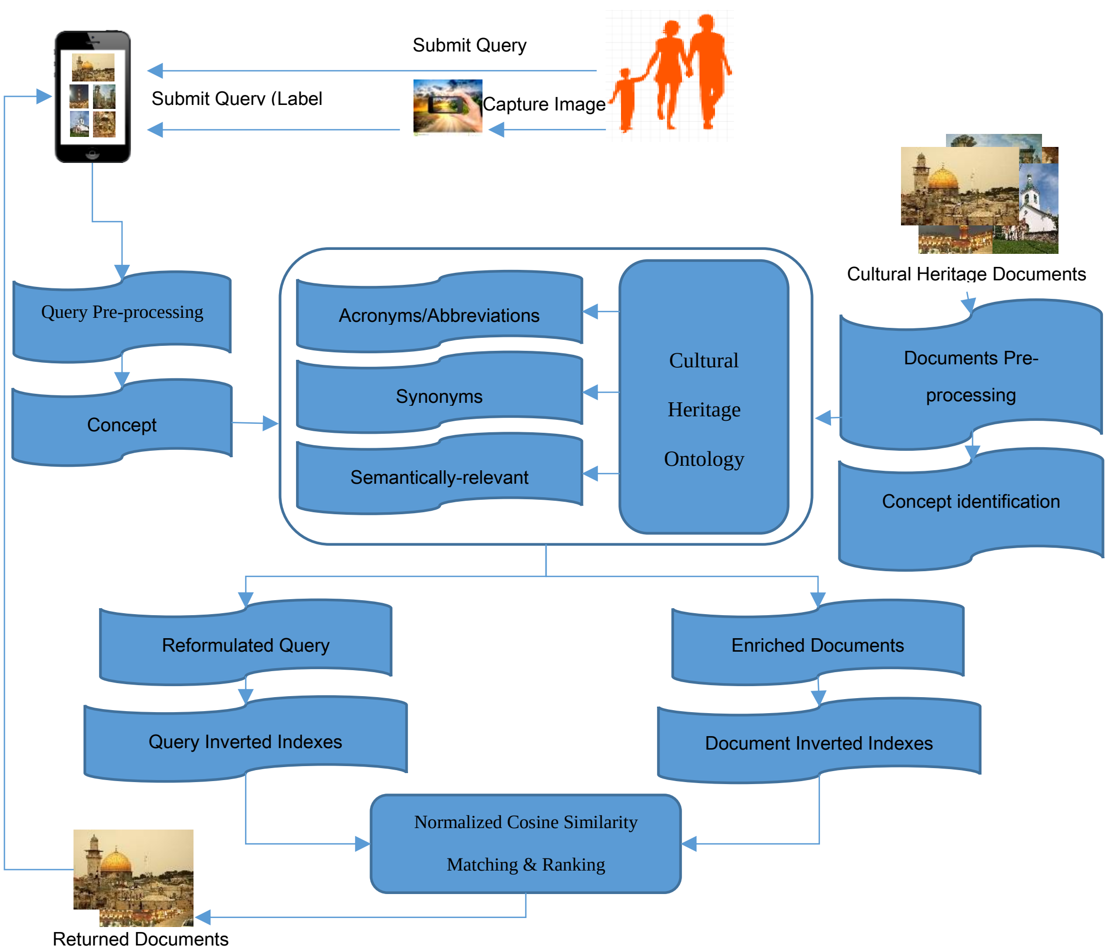


Figure 2. General overview of the architecture of the proposed system

In the next sections, we introduce more details on each of the exploited modules by our proposed system. We first introduce the Holly-land ontology and then discuss the features of the recommendation modules.

3.1.1 Holy-Land Ontology

The exploitation of ontologies is perceived as a potential solution that can be employed for the purpose of improving data and information access to digital cultural heritage content [82]. The adoption of semantic technologies and semantic resources for enabling semantic access to cultural heritage content; in an attempt at facilitating interoperability across distributed systems, sharing, use and reuse of knowledge across various data sources and knowledge repositories has been the focus of a number of recent research projects in the cultural heritage area. For instance in [83], the authors discussed the benefits of exploiting ontologies for offering seamless access to digital content and also for enabling content integration; considering the requirements and needs of end-users. The need for services, tools and applications that assist tourists to find and access cultural heritage digital data resources for traveling purposes has captured researchers' interest to build ontologies for specific cultural heritage contexts such as mobile-based cultural heritage recommender systems. Given the particularities of cultural heritage content, the ontology can form the backbone of any mobile-based recommender system as it represents the knowledge of this domain and enables the sharing of commonly recognized and shared concepts in this field. Without the ontology, or the concepts that underlie knowledge, there can be a gap among the vocabulary used to express users' interests and its corresponding content. According to McGuinness and Harmelen, there are five items that briefly describe the reasons to create ontologies in this context [13, 14, 84]. These are:

- To enable sharing a commonly agreed upon understanding of the conceptualizations about the domain of interest.
- To provide users with the ability to use and reuse background domain knowledge.
- To explicitly define entities and their associated relations and instances.
- To separate the captured knowledge about a given domain from the operational knowledge related to it.
- To enable analyzing and further extending the domain knowledge.

Through our review of previous studies, and to the best of our knowledge, we not found any ontology that maintains or describes Palestine's cultural heritage. However, as we have also noticed that a considerable attention has been given to the issue of developing, preserving, as well as promoting cultural heritage content in Palestine in recent years. As such, we have established one of our research goals for constructing ontology for Palestine area and decided to call it Holy-Land ontology. In the design of this ontology, we have discussed the ontology's scope for Palestine's cultural heritage sites, which may include vocabulary describing the conceptual, cultural, heritage, archeological aspects in Palestine sites and the relationships between these elements. The suggested ontology maintains the diversity of the Holy-Land cultural heritage within the following main types:

History of modern arts (religious objects, drawings, photography, figure, architecture, manuscripts), design (furniture, tableware, etc.), science and technology (equipment, tools, weaponries', famous, discoveries), ancient heritage (agreements, cultures, manuscripts, drawings, photographs, personal objects, weapons), ethnology (fashion, tools, weapons, household items, Religious beings , Etc.), non-moving sites (architecture, rock art, caverns), and monuments (messages, statues, tools , Weapons, household, human remains). Figure below provides a high-level overview of the constructed Holy-Land ontology.

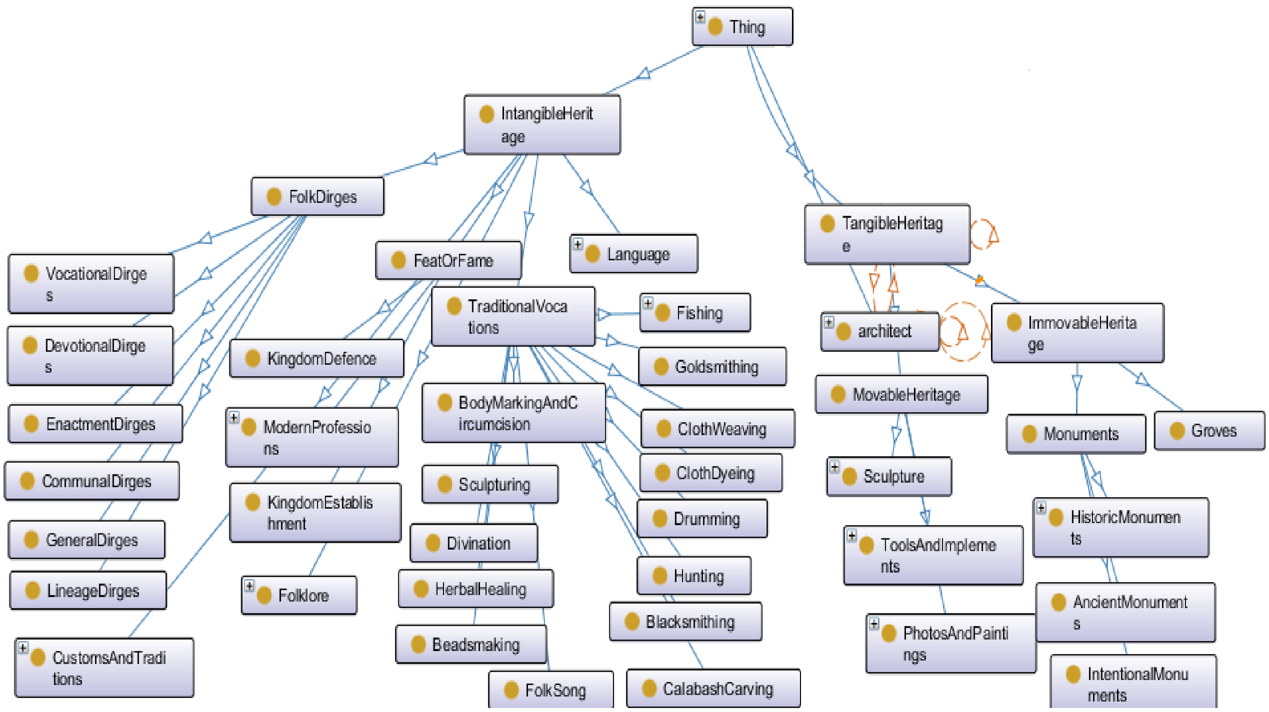


Figure 3. High-level overview of the proposed Holy-land ontology

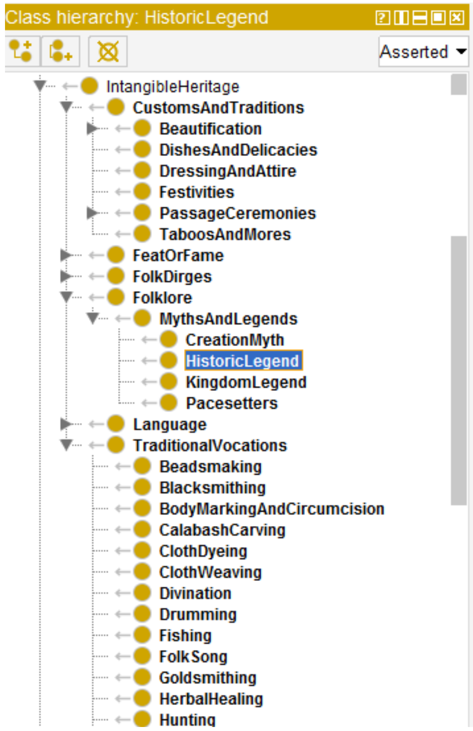


Figure 4 High-level overview of the proposed Holy-land ontology

3.1.2 Mobile Recommendation System

The main focus behind designing mobile recommender systems is to be able to retrieve results to users that they are evaluated and judged as relevant to their information needs. This in return allows users to have a more efficient interaction with the system as their time and usage context is utilized through displaying results that are meaningful to them and they are not any more concerned about evaluating results that maybe irrelevant to their initial information desires. Another important advantage of mobile-based recommender systems is that they can be used in any place when especially internet connection is available. This makes it easier for tourists to use this feature while they are travelling; enabling them to acquire ad-hoc information that can be utilized to improve the quality of the produced recommendations. In addition to the features provided by mobile devices, the camera can be also utilized to take pictures that can be used as system input to retrieve information on subjects related to those images, whether by extracting the text or objects that appear inside them. Moreover, with the existence of GPS hardware component; which has become an important element in most of the mobile devices, users can use this feature to submit system input to locate the user's current location which in return helps in retrieving relevant recommendations about nearby cultural heritage sites and locations.

3.2 Theoretical Basics and Formulations

3.2.1 Search functionalities:

As stated in the previous section, our goal is to better facilitate users' access to cultural heritage content by providing them with multiple search functionalities. In the next sections, we described each of these search functionalities in details:

- **Search by current location:**

Using this feature, we allow users to explore all archaeological and historical sites that are nearby a certain distance from the user. This is accomplished through integrating a Google's map with the search location bar to allow obtaining the address details or current address details with respect to the current location. The following algorithmic steps are employed to get the current location of a user and his/her nearby locations with 10 km distance and 360-degrees radius in an attempt to retrieve all historical and cultural places in this area:

Algorithm 1. Pseudo Code for Search based on the latitude and longitude

```
Input: Current GPS Location (latitude longitude)
Distance around the current location:
Calculate all point around the current location.
Output: list of locations nearby
1:  GPS Location (latitude, longitude)←⟨⟩
2:  toRadios return Math * PI /360 ←⟨⟩
```

```
toDegree  return * 360/Math * PI←⟨⟩
pointA = new google.maps.LatLng(latit, longit)
radiusInKm = 10
pointB = pointA.destinationPoint(180, radiusInKm)
Return pointB
```

- **Search by camera Input:**

Mobile devices nowadays are equipped with many hardware and software components and tools like camera, sensors, tool kit… They have become much more powerful than ever before and techniques that they use have become more efficient and effective. The integration of such powerful features and components has made it possible to incorporate machine learning algorithms, namely for carrying out more complex tasks that used to be impractical to accomplish on ordinary mobile phones. As such, we implemented a module for recognizing objects and detection of texts in image contents on android devices by using machine language tool kits that are use a three-ways label detection, object recognition, and face detection algorithms. In the context of our work, and in coping with these recent advancements, we have used machine learning (ML-SDK) kit in our application to recognize and extract text from images, and to detect, track and classify objects in static images captured by the mobile camera. In our approach, we investigated image processing methods and machine learning and modeling across three aspects: text detection, text recognition and object detection. For text recognitions; we implemented the Optical Character Recognition (OCR) technique to extract text from images taken by tourists. The following algorithmic steps are used to detect the text in the image to allow users retrieve cultural heritage documents related the label that is recognized among the image:

Algorithm 2. Pseudo Code for Search based on Text Detection in captured image

```
Description:
Input: Image[bitmap binary]:
txt = ocr (I) Returns an ocrText object from the input image, I. The
object contains recognized text, a text location.
Txt = ocr (I, roi) recognizes text in I
[___] = ocr (___, name, value) Use additional options by one or more
value pair arguments.
Output: list of predicted doc recognition
    captured_image ←⟨⟩
    Generate sub-segmentation ←⟨⟩
    for  I←0; I < Rq_Capture_list.region; I++
     (Text = OCR(I)
    Text= OCR(I,roi)
            if captured _list[j] IN related_similar_list then
                ADD [___] =ORC (___,roi);
            end if
     end for

    Return relevant_doc_list
```

Success of modeled object detection depends on the accuracy of classification the objects recognition and detection in the image captured by the camera. Machine learning (ML) kit support many algorithms for recognition and detection the objects form static images captured by the mobile camera, R-CNN (Regions Convolutional Neural Network) that using an algorithm called Selective Search which reduces the number of bounding boxes that are fed to the classifier to close to 2000 region proposals, that's one of Convolutional Neural Network (CNN) the state-of-art that based on deep learning object detection methods. In our mobile application we using Regions Convolutional Neural Network (R-CNN) modules and its algorithms to recognition and classification an objects in an image and predicts the object in an image that captured by the mobile camera.

The following algorithmic steps are used to detect the objects in the image to allow users to retrieve cultural heritage documents related the objects that are recognized from the input image:

Algorithm 3. Pseudo Code for Search based on Object Recognition by using Camera as a second search technique to retrieve information about the objects recognized from the captured image

```
Input: An image [bitmap binary]: Extract region proposals [around
2000 candidate region] For each region proposal:
Warp it to a size fitted for the CNN.
Compute the CNN features.
Classify what is the object in this region.
Output: list of predicted object labels
    captured_image ←⟨⟩
    Generate sub-segmentation ←⟨⟩
    for  i←0; i < Capture_list.length; i++
     (captured _list[i])
    //combine similar regions into larger ones
     for  j←0; j < related_similar_ captured _list; j++
     if captured _list[j] IN related_similar_ captured _list
     then
                 ADD (captured_img_list)
              end if
      end for
    // produce the final candidate region proposals
    Return relevant_label_list
```

- **Search by text Input:**

Using this option, users can search using queries wherein we exploit a number of (NLP) steps to process and formulate the submitted queries. In this context, when a user submits a given query, we employ query reformulation techniques in addition to a set of integrated semantic cultural heritage resources to retrieve cultural heritage information that satisfies users' information needs. Accordingly, for each query about cultural heritage, the system pre-processes its content using a series of steps including tokenizing the query’s text, removing less significant terms (a.k.a. stop words), normalization, and stemming. The output of the pre-treatment process is further handled to identify terms, abbreviations, and synonyms that can refer to cultural heritage concepts. To find the similarity between a given query and its associated cultural heritage documents, we utilize Algorithm 4.

Algorithm 4. Pseudo Code Matching between the reformulated queries and their corresponding cultural heritage documents

```
Input: Initial_Query Qi = {t1, t2, t3, ..., tn} , Initial_Documents Di = {d1, d2, d3, ..., dn}
Output: Set of relevant cultural heritage documents Dr = {dr1, dr2, dr3, ..., drn}
1:   irr_query_terms ←⟨⟩;
2:   rel_query_terms ←⟨⟩;
3:   for each ti ∈ Qi = {t1, t2, t3, ..., tn}
4:      if (isRelevant(ti))
5:          add (ti, rel_query_terms [i])
6:      else
7:          add (ti, irr_query_terms [i])
8:      end if
9:   end for
10: exp_query_terms ←⟨⟩
11: for each ti ∈ rel_query_terms
12:        exp_query_terms ← GET_Synonyms (ti)
13:        exp_query_terms ← GET_Semantically_Relevant_Terms (ti)
14: end for
15: temp_doc_list ←⟨⟩
16:    relevant_doc_list ←⟨⟩
17:    for  i←0; i < exp_query_terms.length; i++
18:          temp_doc_list ← GET_DOCS_FROM_INDEX (exp_query_terms [i])
19:          for  j←0; j < temp_doc_list.length; j++
20:            if temp_doc_list[j] Not IN related_doc_list then
21:                ADD (related_doc_list, temp_doc_list[j])
22:            end if
23:           end for
24:   end for
25:   Return relevant_doc_list
```

As shown in Algorithm 4, the function is Relevant (Line 4) takes each query terms and returns whether it is a candidate for semantic expansion or not. To do this the function tokenizes query terms into uni, bi and tri gram tokens and checks whether each of these tokens is a stop-word or it is recognized by the employed ontology. All tokens that are not recognized by the employed ontology are moved to the set of irrelevant query terms, while the rest of tokens are added to the relevant query terms list. All tokens in this list are further expanded with their synonyms (Line 12) as well as other semantically-related terms (Line 13) based on their definitions in the used ontology. The same steps are applied on the textual content of each cultural heritage document.

3.3 Detailed Characterization of the Proposed System

When submitting a cultural heritage query, it is important to identify whether it contains any of the following parts:

Acronyms: which are used to refer to a longer name of a certain concept and are normally formed from the first letters of their longer names, such as: CHAPS that stands for 'Cultural Heritage and Preservation Studies or CULS which stands for ‘Cambridge University Land Society’.

A second component that may appear in a given cultural heritage query is the *Abbreviations*; which is a term that is normally written in a different form matched to the full name that it represents, such as: Herit. That stands for Heritage.

On the other hand, a query may contain one or more *Cultural Heritage (CH)* terms; which are used to map cultural heritage concepts in the exploited cultural heritage semantic resources to their correspondences in the cultural heritage documents. Example of these terms are: Intangible heritage, Tangible heritage, etc.). A query of course may contain additional *Supportive* terms: which refer to any other terms in the query that the system was not able to classify under any of the main term categories: acronyms, abbreviations, or cultural heritage terms. Examples of such supportive terms are: buildings, archaeology, archives, etc. In the next example, we demonstrate the query processing steps that we carry out in an attempt to analyze its content and classify the terms under their corresponding term categories.

Given the following two queries in the English Language (Uq_1 and Uq_2):

- Uq_1: Materials and artist, and its year of creation (Getty Art & Architecture Thesaurus (AAT) dataset [85, 86]
- Uq_2: Historical events, and archaeology (Getty Art & Architecture Thesaurus (AAT) dataset [85, 86]).

And, given the following two queries in the Arabic Language (Uq_3 and Uq_4):

- Uq_3: قبة الصخرة خلال الحضارة الإسلامية
- Uq_4: معالم اثرية وأحداث تاريخية

To process the queries in above example, we utilize the following modules:

3.3.1 Query Preprocessing

To process user queries at this phase, we use conventional NLP techniques. This includes implementing each of the following steps. First, we normalize query terms through removing all punctuation marks. Then, we remove stop-words based on a list that includes stop-words such as: (is, be, to, at, then, that …etc.). After that, query terms are stemmed using Porter stemmer [27] to find the stem(s) of each submitted term. Finally, we use the NLP n-grams tokenization technique to chunk the given query into uni-gram, bi-gram, and tri-gram tokens. As such, the output of the user's query from the above example becomes as follows:

For Uq_1:

- List of unigrams in (Ut1): [Jerusalem, Rock]
- List of bigrams (Bt1): [Jerusalem, Old Jerusalem, Dome of the Rock, Church of the Holy Sepulcher, Ibn al-khattab, Saladin]
- List of trigrams (Tt1): [Dome of the Rock, Omar bin al-khattab]

For Uq_2:

- List of unigrams (Ut2): [Baha', Sebastian]
- List of bigrams (Bt2): [Baha'i Gardens, Ibrahim Mosque, Roman capital]
- List of trigrams (Tt2): [Maqam of the Prophet Abraham]

For Uq_3:

- List of unigrams in (Ut1): [الصخرة ,القدس]
- List of bigrams (Bt1): [صلاح الدين, ابن الخطاب,كنيسة القيامة,قبة الصخرة ,القدس القديمة ,بيت المقدس]
- List of trigrams (Tt1): [قبة الصخرة المشرفة ، عمر بن الخطاب,صلاح الدين الايوبي]

For Uq_4:

- List of unigrams (Ut2): [سبسطية ,البهائيين]
- List of bigrams (Bt2): [المسجد الابراهيمي, عاصمة الرومان ,حدائق البهائيين]
- List of trigrams (Tt2): [مقام النبي ابراهيم]

3.3.2 Recognitions of Cultural Heritage Term Categories

At this phase, recognized query terms are mapped to their corresponding term categories as detailed in the previous section. In this context, acronyms, abbreviations, CH terms, and other supportive terms are recognized and routed under their corresponding categories. An automatic recognition of the synsets of CH query terms is implemented during this step. To extract both cultural heritage acronyms and abbreviations, we use the AAT lexicon [58] that is provided by the Documents to extract and expand cultural heritage acronyms and abbreviations (being uni-gram, bi-gram, or tri-gram) given in the customer's query. After that the query is then expanded through the addition of the full representations of the extracted acronyms and abbreviations, and also by including their synonyms when available. On the other hand, to extract cultural heritage terms from the user's query, we use the develop tool which maps cultural heritage texts to the AAT thesaurus. It locates all the AAT concepts associated with terms in the cultural heritage documents using the knowledge intensive method that is based on natural language processing and computational linguistic techniques [39, 87].

3.3.3 Matching and Ranking

In this section, we talk over the techniques used for marching and ranking the returned results to the users. In the context of our application domain, we have utilized the normalized cosine similarity formula for carrying out the matching and ranking task. Inspired by the work proposed in [88], we have adapted the same ranking technique which is employed to assign higher weights for cultural heritage terms (CHt, ACt, $ABBt$, $SYNt$) against other supportive terms $Suppt$, and also against the full representations of acronyms and abbreviations Et that are automatically added to the initial user's query. To implement the proposed technique, we have used the vector space model (VSM) a.k.a. cosine similarity model [15, 48, 57, 89] for assigning relevance scores between each given user's query Uq and the documents d in the document collection D. The cosine similarity model employs the $tf-idf$ weighting scheme to assign a weight for each term t in a document d. By utilizing the normalized version of this algorithm $Normalized-tf_{t,d}$ term occurrences are usually normalized to avoid bias toward longer documents (may contain more numbers regardless of the actual significance of the term in the document) to give some importance of the term t within the particular document d:

$$Normalized-tf_{t,d} = \begin{cases} tf_{t,d} / |d| & if \quad tf_{t,d} > 0 \\ 0, & Otherwise \end{cases} \tag{1}$$

Where $tf_{t,d}$ is the number of occurrences for term t in d, and $|d|$ is the length of the document d.

The same weight as its original form which is typed by the user (In Example1-Uq_2: the term 'الحرم القدسي' and its synonym 'المسجد الاقصى' have the same weight). But, we reduce the weight of all other terms Et that are semantically associated to the original user query terms but with semantic relations other than synonymy (In Example1- Uq_1: the term 'المسجد الاقصى' is given higher weight than its full representation ('القدس الشريف'الحرم القدسي').

Our similarity model handles both document d and query Uq as vectors. Assuming $\vec{d}$ be the vector representation of d, and $\vec{Uq}$ is the vector representation of Uq. To assign relevance scores between these two vectors, the following:

$$sim(d,Uq) = \cos ine(d,Uq) = \frac{\vec{d}.\vec{Uq}}{|\vec{d}||\vec{Uq}|} \tag{2}$$

The following algorithmic steps demonstrate the matching process between each reformulated query and its corresponding cultural heritage documents:

Algorithm 5. Pseudo Code Matching between the reformulated queries and their corresponding cultural heritage documents

Input: Rq_terms_list [t1, t2, …,tn]

Output: list of relevant cultural-heritage documents

```
temp_doc_list ←⟨⟩
relevant_doc_list ←⟨⟩
for  i←0; i < Rq_terms_list.length; i++
      temp_doc_list ← GET_DOCS_FROM_INDEX (Rq_terms_list[i])
      for  j←0; j < temp_doc_list.length; j++
        if temp_doc_list[j] Not IN related_doc_list then
            ADD (related_doc_list, temp_doc_list[j])
        end if
       end for
end for
```

```
11:   Return relevant_doc_list
```

As shown in Algorithm 5, the results of the matching function are returned as a list of relevant cultural heritage documents that are ordered in a descending manner starting from the most relevant document (the first result with the highest number of matching terms) moving downwards towards the least relevant document (with relevance score > 0). In the next section, we discuss in details the experiments that we have carried out to validate our proposal approach.

3.3.4 Recommendation Module

Among the key features and services that are provided by the proposed system including the recommendation module, are the exploration of the cultural heritage information unit and the registration of CH information and updates devices location [1, 5, 68, 90]. In this context, the proposed hybrid recommendation system combines several recommendation techniques to yield more accurate outputs. As we have pointed out earlier, when comparing hybrid recommendation applications against cooperative or content based recommendation applications, the precision of the recommendation is usually higher in hybrid application. This is because there is no prior information about domain precision when employing collaborative filtering, and about people's preferences when employing content-based applications. Therefore, hybrid techniques play essential role in designing the recommendation application. Our suggested recommender application generates suggestions for users through the combination and integration of both collaborating filtering on data with rating predicted with content-based filtering and item similarity. The final score is a produced in the form of a weighted sum of scores that are computed automatically from transaction data, user data and items retrieved. In our work, we proposed a new way of classifying predictions; collaborative filtering techniques and content-based filtering are integrated, where five existing data sources were used based on content - user preferences - cosine results – search context, and previous location to make recommendations to users. And get weights for each component, as: 50% content based + 10% Preferences + 20% Cosine Results + 10% previous searches + 10% Location. Accordingly, each score is automatically calculated based on the weighted sum of five values:

1. Content-based (50%): Score estimation by computing similarity with item that user wants to find.

2. Users preferences (10%): Score scale from 1 star to 5 stars, where one star implies "dislike" and five stars implies "excellent", if he /she visit this data or not do that.

3. Previous search (10%): Record what the user is searching for, including keywords, where the user is located, and what results are personalized and satisfactory.

4. Location (10%): User location - like nearby cultural heritage locations.

5. Nearest-neighbor (20%): Similarities between pair of items are computed using cosine similarity metric.

Content-Based Filtering

To develop content-based filtering techniques, user's preference and the descriptions of terms play a crucial role in realizing such techniques. We describe terms by using keywords from the generated user's profile to point to their preferred likes or dislikes across the entire dataset. Content based filtering algorithms recommend terms or similar to terms that were liked in past usage contexts. In this context, a recommendation algorithm examines what items have been previously rated by users and accordingly produces recommendations that attempt to best matching highly-rated items. To develop our proposed recommender system, we have implemented KNN algorithm (nearest neighbor) to select the most associated items to the targeted terms. The suggested ratings using the Pearson association match measure are calculated as the weighted average of deviations from the neighbor's mean [91] using the following formula:

$$r_{u,i} = \bar{r}_u + \frac{\sum_{v=1}^{n} (r_{v,i} - \bar{r}_v) * P_{u,v}}{\sum_{v=1}^{n} P_{u,v}} \tag{3}$$

Where ($r_{u,i}$) is the predicted rating of the consumer (u) on the term(i; $\bar{r}_u$) is the mean rating given by the consumer (u; $P_{u,v}$) is the Pearson association similarity between consumer (u) and (v); and (N) is the number of consumer in the neighborhood.

Collaborative filtering

Collaborative filtering systems deliver recommendations based on users' historical preferences for terms by (click, view, share, like, rate, etc.). The preference can be given as a matrix for the user element. Here is an case of an array describing the preference of 3 customers over 5 elements, where p $_{[11]}$ is customers preference 1 over term 2.

$$p = \begin{pmatrix} p_{11} & p_{12} & p_{13} & p_{14} & p_{15} \\ p_{21} & p_{22} & p_{23} & p_{24} & p_{25} \\ p_{31} & p_{32} & p_{33} & p_{34} & p_{35} \end{pmatrix}$$

Nearest-neighbor based on Collaborative filtering

Nearest neighbor based techniques are based on the difference between pairs of terms or users. Cosine similarity is often used for measuring the distance.

$$sim(d, Uq) = \cos ine(d, Uq) = \frac{\vec{d} \cdot \vec{Uq}}{|\vec{d}||\vec{Uq}|} \tag{4}$$

The preference matrix can be represented as terms vectors: $P = [X_1, \ldots, X_n]$

Building User's Profile (Users preferences, previous search):

In the context of our work, a customer's Profile Agent is required to be able to construct and further manage user profiles. Therefore, a user is requested to fill out a form that shows his/her preferences and interests on a registration page. So, through the utilization of users' submitted information, the developed Profile Agent can track user logs during their interaction with the system and accordingly suggest results and be able then to infer new preferences based on their usage context. This also helps in semantic query handling and enrichment to expand user queries with more information about their preferences. In addition, this helps in post-processing the generated recommendations and also in personalizing users' experience with the developed application. For example, the profile agent can measure the frequencies of certain terms in the user's queries to help in expanding and enriching the query when it is reformulated.

Location aware mobile devices:

Using GPS attributes, we can acquire information about the current user location, to provide physically nearby places, historical events that have taken place in the nearby locations, in addition to other relevant information such as artworks that were built in the returned list of close locations and information about artists whom may have lived there. In our method two types of information are joints: general information about geolocations and points of interest and specialized information about the cultural heritage domain.

In general, there are many mixed methods: weighted, toggle, mixed, a combination of features, increased parameters, and cascade and definition level [20, 24, 51, 92, 93]. Weighing revolves around the output of the various recommendation application elements combined using a linear weight system. Most studies combine collaborative filtering with another technique often in a weighted way, which means that weighted hybrids are the most frequent. They calculate the recommended element scores by aggregating the output scores for each recommendation technique using the weighted linear functions. We proposed these weights for each component: 50% content based + 10% Preferences + 20% Cosine Results + 10% previous searches + 10% Location. By using a linear weighting method, the weighted hybridization yields the results by joining the yield of two or more elements, and the utilized hybridization formula can be formulated as described in by the following equation:

$$P = \sum_{i=1}^{n} c_i p_i \qquad (5)$$

Where P_i is the result produced by the recommendation component $_i$, and c_i is the weight of the component $_i$.

3.4 Summary

Our goal in this chapter was to construct available a whole overview of our proposed application and to clarify the overall construction of the proposed application. In addition, we highlighted the role for each component in successful the quality of the proposed application.

In this work, we introduced the main components of the proposed “Multi-Lingual Semantics-Based Cultural Heritage Recommender Application for the Palestine”, and we have explained the process of constructing a special ontology for Palestine’s cultural heritage through enriching it with other ontologies in this domain, to join the semantic gap between mixed content descriptions to provide contextual and relevant information that meets users’ requirements in terms of user interest in keywords and locations visited. The system uses the information retrieval framework where context data is used and the search results are grouped into the content of the recommendation appropriate for mobile users. As highlighted in the sections of this chapter, our proposed system mainly comprised three main components: Holy-Land Cultural Heritage Ontology, the Query Processing and Expansion module, and Matching and Recommendation module.

CHAPTER FOUR - A PROTOTYPICAL IMPLEMENTATION

In this chapter, we presented the operation details of our proposed mobile-based system. First, we presented the details that pertain to the Multi-lingual Semantics-based e-Cultural Heritage Recommender system in section 4.1. Then, in section 4.2, we explain the Textual vs. Query-by-Example Interfaces. Then, in section 4.3, we described the Coupling Textual and Content-based Cultural Heritage Information. Then, in section 4.4, we describe User Preference-based Refinement of Recommended Cultural Heritage Information; finally, we summarized this chapter in section 4.5.

A Prototypical Implementation

We developed a prototype of the suggested mobile-based application with a cultural heritage search interface with multi-functions that facilitate users' access to cultural heritage documents in the dataset. In this context, the user can submit his cultural heritage query in the form of a natural language query. Accordingly, the application assigns relevance scores between each pair of query-documents based on their semantic similarity. The application provides set of most relevant information that best meet their needs. In addition, the application lets end users to use their current location information (to retrieve historical places and events that are nearby the place where the visitor is located), considering network availability. Moreover, it allows the user, when visiting any place, to take pictures of what they have been inspired by and upload those pictures online to share their practices with their friends, enabling them to analyze these pictures, in addition to their captions (textual descriptions that are associated with each picture and other contextually-relevant information). An example of this contextual information is the user's personal characteristics (such as preferences, previous knowledge, and visitor behavior), current location or current time (historical events associated with the place where the visitor is located).

1.1 Multi-lingual Semantics-based e-Cultural Heritage

In cultural heritage recommender applications, there are digital libraries that are collectively acquired to formally depict cultural heritage content and present it to users through a variety of information access techniques and channels [94]. Among the primary goals of cultural heritage based recommender system is to enable users (tourists or even ordinary users interested in this domain) search, explore, access and share information about cultural heritage objects coming from museums, libraries and archives. In an attempt of realizing this objective, we aim to build ontology for a recommender system to communicate Palestine’s cultural heritage and make it accessible in different languages, such as, (Arabic, English, Hebrew and France). This is a great technical challenge not only for multilingual content but also for users who speak more than a different language. Ensuring that users can find relevant objects even in languages they are not familiar with requires complex algorithms and user interactions that bridge the language gap. In XML and RDF data, it is suggested that the xml: lang attribute be used to specify which language to describe the specific data. This is used in the case of multiple languages within the metadata. We worked to add language tags to the metadata to the distinct text string values within the metadata. In this case, each of the keyword terms has a matching language tag; making it possible to display the suitable language based on the preferences of users.

1.2 Textual vs. Query-by-Example Interfaces

When we search for information, such as cultural heritage in Palestine area, we wish more relevant and precise information to be collected from reliable sources and using various search functionalities. This leads us to exploiting multiple kinds of approaches and integrates them in one robust system, which supports different interaction styles. Old-fashioned search engines depended more or less exclusively on recognition of keywords or patterns of keywords in the text material. By contrast, the employed Holy-Land ontology addresses retrieval of related text segments based on the conceptual content of the text. Queries take the form of natural language expressions and the system is primarily intended to retrieve text segments whose semantic content matches the content of noun phrases in the query phrase. This is critical in the cultural heritage domain when some cultural heritage is restricted to users because of their life conditions and the facts about these cultural heritages. To perform a search through metadata or portions of the original texts represented in the data set (such as titles, summaries, and selected sections), a search engine examines all of the words in every stored document as it tries to match search criteria (for example, text specified by a user). On the other hand, Query-by-Example (QBE) is a technique of query creation that allows the user to search for documents based on an example in the form of a selected text string or in the form of a document name or a list of documents. A query is created using the relevant words (without stop words, such as "and," "is" and "the") and a search is carried out for documents containing them. Additional feature in our system allow users to search depending on images as input query examples, or search depend on specific location to retrieve all relevance items and documents related on this query example.

1.3 Coupling Textual and Content-based Cultural Heritage Information

In view of the textual material, the texts of our corpus are gathered from the following classifications: (a) literary works written by authors from Palestine and the surrounding areas or with a story located in Palestine; (b) folklore texts, i.e. those depicting a wide range of aspects of human activity such as traditions Customs, practices, spiritual beliefs and other aspects of daily life in the eligible areas; and (c) popular stories and legends from all parts of Palestine.

Nowadays recommender application represents the major area where standards and techniques of Information Filtering are applied, such as, content-based and the collaborative-based filtering approaches. This work is focused on a hybrid-based recommender application. The content-based search element is more suitable for the cases where users feel that they can provide prototype multimedia content which is similar to the content they are looking for. A customer is able to provide, as the input query, an example of the multimedia content she/he is interested in, and, based on the extracted descriptors of the input and the stored offline-generated descriptors of the content repository, the application performs a visual similarity-based search and relevant results are retrieved. For proper address of the several content types, various strategies are used for each type in the offline analysis process.

1.4 User Preference-based Refinement of Recommended Cultural Heritage Information

One main job of the User's Profile is to enable discovering and gathering new preferences based on the end user's communications and behaviors. The favorites can be knowledgeable by exploring the User's Interactions Log which contains the user's communications. We implemented user preferences to get most relevance to the user in our recommender system module. The user's profile is represented in different ways, allowing the users to rank the results between (1-5) to know what results that he/ she likes and dislikes depending on the query submitted, the most terms that users search about, the basic cultural information of the end user such as his/her location.

Then, the end user's manipulation statistics information such as his/her older searches and visited links, the profile gets reorganized by analyzing the interactions of the end user on the results and hence this improves the future results, i.e. when the end user always selects a specific cultural heritage from the outcomes then the profile gets updated such that the end user likes this specific content.

1.5 Summary

The goal of this chapter was to present the methods and techniques that are used in our proposed system. In addition, we have demonstrated that the proposed system has two components, constructed ontology and recommender application. The size of digital cultural heritage records is huge and fast increasing. The load of art information has created the need to help people and provide them with the most appropriate way to access cultural heritage information. The Results of the proposed recommender system depend on personalization features, with collaborative methods: (1) use of ontologies as distributed terms and thesauri to model the domain of art; (2) an collaborating ontology-based elicitation of user interests and preferences in art to be stored as an extended overlay user model; (3) used Semantic Query Manipulation for enhancement the results; and (4) Multilingual Metadata and Multilingual Objects (queries). As demonstrated in the next chapter, we survey a user-centered design for collecting needs, examination out design choices and evaluating phases of our prototypes.

CHAPTER FIVE - EXPERIMENTAL INSTANTIATION

In this chapter, we presented the experimental steps that we carried out to assessment the quality of our suggested mobile-based application prototype. We mainly introduced the experimental instantiation, evaluation methods and techniques, used datasets, and prototype implementation and evaluation results. We would like to point out that our prototype and experiments have been carried out on a PC with core i7 CPU (2.5GHz) and (16 GB) RAM. For building the application prototype, we used Java programming language with machine learning kit library, and we used SQLite database to build our inverted indexes and API to retrieve data from our dataset. We have performed offline local copy of the exploited semantic resources (AAT thesaurus) during the indexing processing. The developed prototype offers users with multi-lingual and multi-feature search functionalities as we have pointed out in the previous chapter. In the next sections, we describe the evaluation steps for these features.

5.1 Experimental Instantiation

This section describes the dataset and tests that we have carried out to evaluate the methods of our proposed system. We start by describing the dataset used for evaluating our system Holy-Land ontology enrichments with Art & Architecture Thesaurus (AAT) and the semantic thesaurus DBpedia dataset 3.9). Next, we present the details of the conducted experiments and their associate results that are produced by our system.

5.1.1 Dataset

In direction to estimate the achievement of the suggested mobile-based application, we used a Holy-Land ontology that enrichments with subset of the Art & Architecture Thesaurus (AAT) and the semantic thesaurus that is an organized vocabulary of around 44,000 concepts, containing

356,000 terms [30, 70, 86, 95], descriptions, bibliographic citations, and other information relating to fine art, architecture, decorative arts, archival materials, and material culture. The selected dataset is an evaluation collection for CHIR with the following format:

- Document Collection: consists of automatically crawled metadata in different formats from web pages that belong to various cultural heritage web sites. The AAT classification system as well as its hierarchical structure including:
    - Associated Conceptions: such as beauty, balance, connoisseurship, metaphor and freedom.
    - Physical Attributes: such as size, shape, texture and hardness such as strapwork, borders, round, waterlogged and brittleness.
    - Styles and Periods: such as stylistic groupings and distinct chronological periods.
    - Agents including people, groups of people, and organizations such as printmakers, landscape architects, corporations, religious orders.
    - Activities such as areas of endeavor, physical and mental actions or methods, such as archaeology, engineering, analyzing, contests, exhibitions, running, drawing (image-making), corrosion.
    - Materials including physical substances, such as iron, adhesive, emulsifier, artificial ivory, millwork, and nylon.
    - Objects either given form by human activity, such as paintings, amphorae, facades, cathedrals, gardens
- Queries: we have used 42 queries to test the system's precision in retrieving relevant cultural heritage documents to these queries. The queries are in both English and Arabic Languages. Below, we provide a sample of the used queries:

"حائط البراق"
"البلدة القديمة في القدس"
"Bahai Holy Places"
"Tels–Meiddo"
"Old City Jerusalem"
"Old City and Walls of Jerusalem"
Old City hebron"
" Old City betlahym"
" Old City nablus"
"Wadi el–Mughara"

SPARQL Query:

```
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://dbpedia.org/ontology/Event>
PREFIX PSH: <http://www.ontologyPSCulturalHeritage.org/ekp/owl/Architect.owl#>

SELECT ?x (STR(?lab) AS ?label) ?labelData ?commentData ?labPers
WHERE {

{
?x PSH:title_heritage ?labPers FILTER("القدس").
}
} order by ?labPers
```

SPARQL Query:

```
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://dbpedia.org/ontology/Event>
PREFIX PSH: <http://www.ontologyPSCulturalHeritage.org/ekp/owl/Architect.owl#>

SELECT ?x (STR(?lab) AS ?label) ?labelData ?commentData ?labPers
WHERE {
{
?x PSH:title_heritage ?labPers FILTER("alquds").
?x rdfs:label "links to City@en".
}
} order by ?labPers
```

- Relevance Assessments: are collected from assessors (not experts in cultural heritage domain) using Relevation [19] which is a system for performing relevance judgments for the evaluation of Information Retrieval systems.

  The relevance estimation is based on a four-point scale. The relevance scores are:

  - Where a document is irrelevant to a given query.
  - Where a document is on topic of a given query but it is unreliable.
  - Where a document is relevant to the given query.
  - Where a document is highly relevant to the given query.

  These relevance scores are mapped into a binary scale, with grades 0 and 1 corresponding to the binary score 0 (irrelevant) and score 2 and 3 corresponding to the binary score 1 (relevant).

5.1.2 Validation

Recommender application accuracy is popularly evaluated through Root Mean Square Error (RMSE) is a compute the spreads out these residuals are. In other words, it tells you how determined the data is around the line of best fit. To evaluate our Recommendation system accuracy, cross-confirmation [68, 96, 97] is used. We create 5-fold confirmation to estimate results. Ranking estimate is the average of the results of experiments on 5 training and test datasets. We use RMSE to compute the error in our Recommendation System as follows:

$$RMSE = \sqrt{\frac{\sum_{(u,i=1)\in TestSet} (r_{u,i} - r_{u,i})^2}{|TestSet|}} \quad (5)$$

Where ($r_{u,i}$) and ($\hat{r}_{u,i}$) indicate the actual and guessed rating. Minor value of RMSE, more precision a rating estimate. But, recommender applications try to make a tradeoff between the precision and coverage. As mentioned earlier, the coverage is the number of pairs < user, item > for which we can estimate a rating. In order to have the coverage and the precision in the same metric measure, we use the F-measure as follows:

$$\text{F-Measure} = (2.\text{Precision} \times \text{Coverage})/(\text{Precision} + \text{Coverage}) \quad (6)$$

5.2 Analysis and Discussions

In this section, the test results are separated into two parts: 1) the first part presents the development of a cultural heritage recommendation application based on Android mobile platform and the second part the construction of the ontology for the Holy-Land area and evaluating the concert and fulfillment of the mobile-based application. The following figures depict real usage context scenarios while experimenting and evaluating the developed prototype.

Implementation Details and Usage Context Senarioes	
1 **Senaior 1: Search by user query inputs**: **Quesry**: "jerusalem" , **Language**: English	

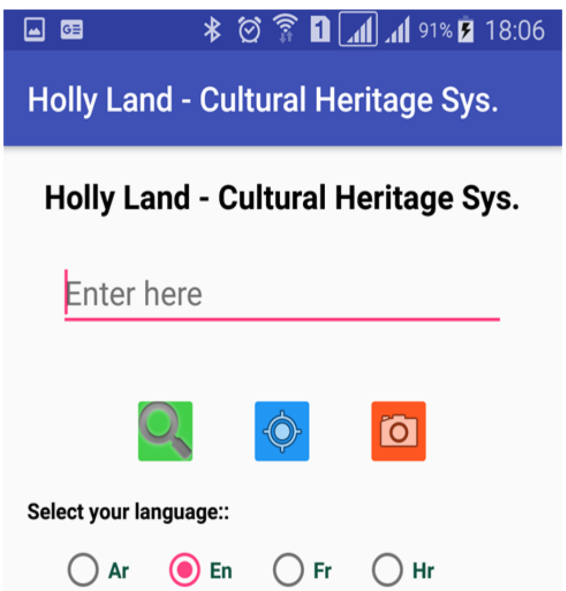



Figure 5. A screenshot of main application – English language is selected	Figure 6. A screenshot of a user submitted query

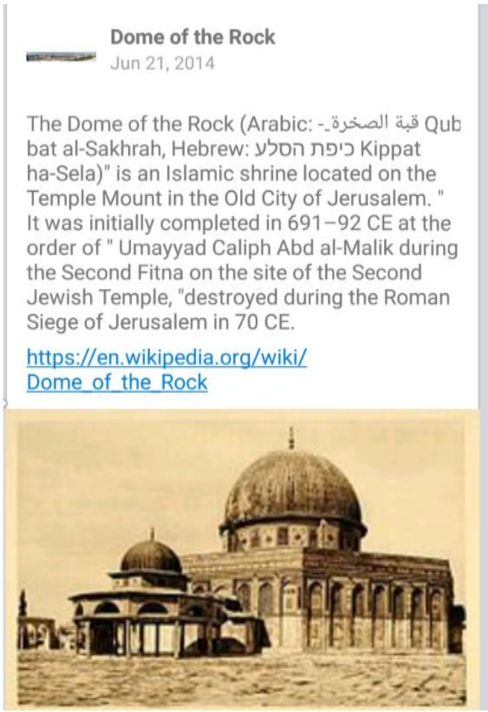


Figure 7. A screenshot of a first result returned for the submitted query – English CH

Figure 8. A screenshot of a second result returned for the submitted query – English CH

2 **Senaio 2: Search by user query inputs**:
Query: “القدس”, Language: Arabic

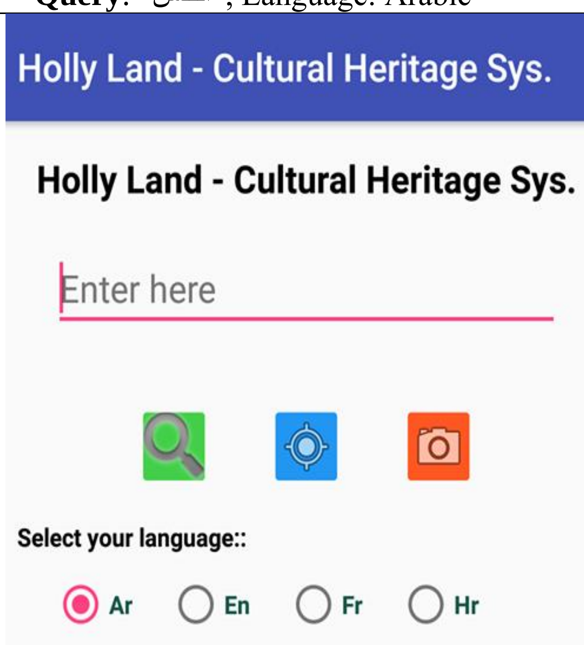


Figure 9. A screenshot of main application – Arabic language is selected

Figure 10. A screenshot of a user submitted query

Figure 11. A screenshot of a first result returned for the submitted query – Arabic CH

Figure 12. A screenshot of a second result returned for the submitted query - Arabic CH

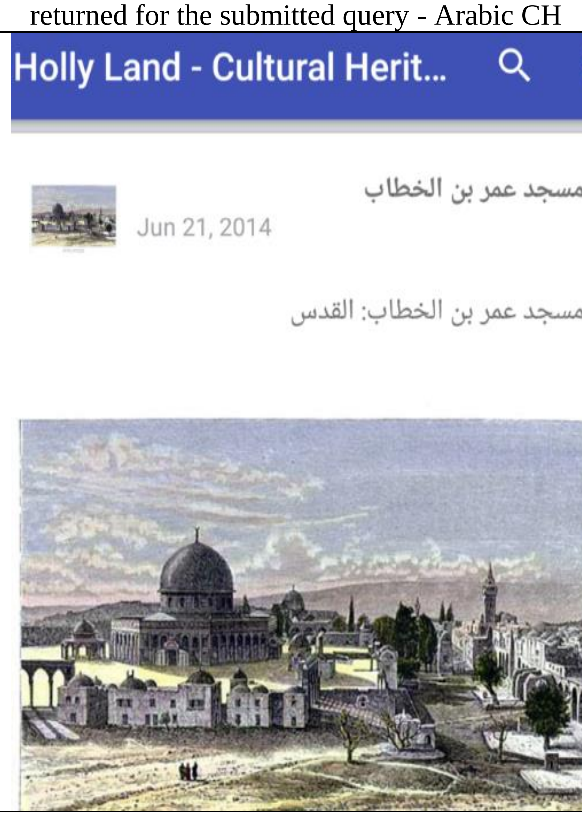


Figure 13. A screenshot of an Arabic uni-gram query

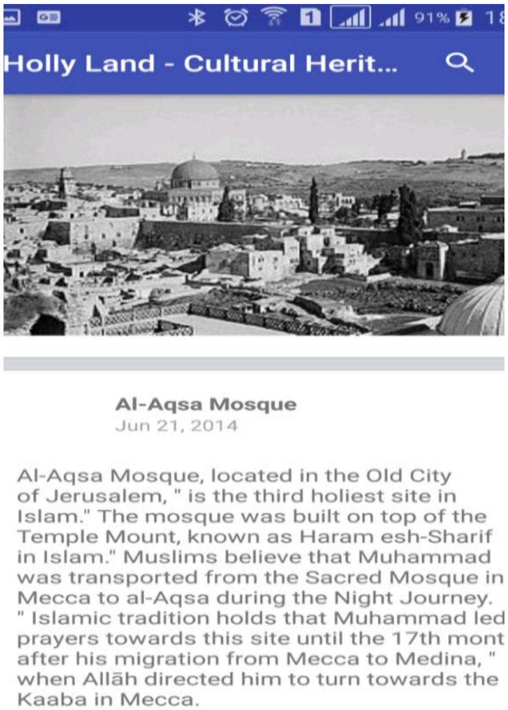


Figure 14. A screenshot of an Arabic tri-gram query

Figure 15. A screenshot of an English bi-gram query

Figure 16. A screenshot of an English verbose query

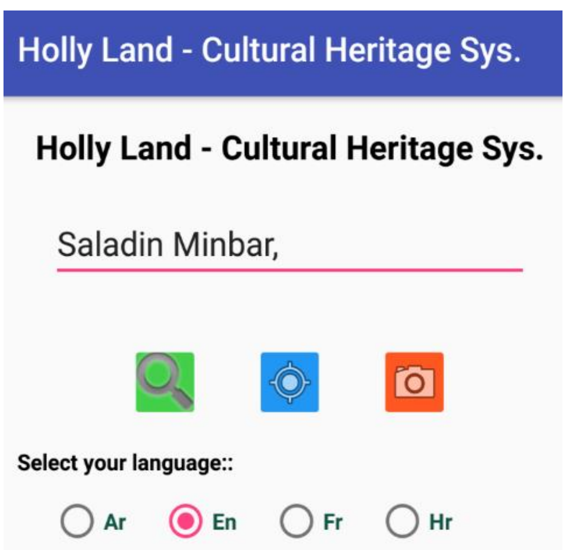
Figure 17. A screenshot of an Arabic bi-gram concept "تراث شعبي" with an example result

Figure 18. A screenshot of an Arabic bi-gram concept "تراث شعبي" with a second example result

Figure 19. A screenshot of an Arabic bi-gram concept "تراث شعبي" with a third example result

Figure 20. A screenshot of an Arabic bi-gram concept "تراث شعبي" with a fourth example result

3 Scenario 3: Search by user's Location:
Query: "user around akka" - place.



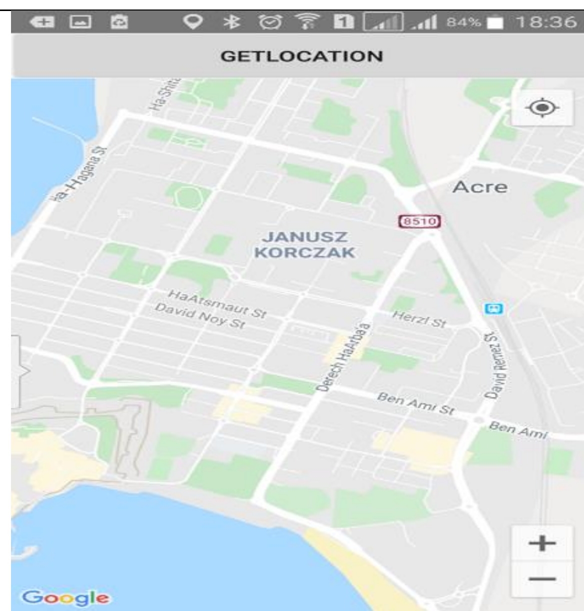


Figure 21. Main application interface – Location icon is selected

Figure 22. Locations found on the map

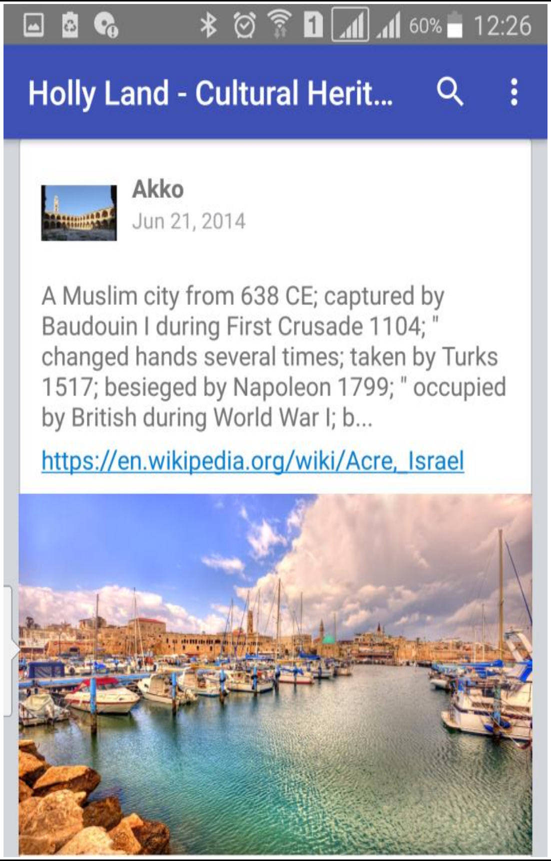


Figure 23. Location-based first result

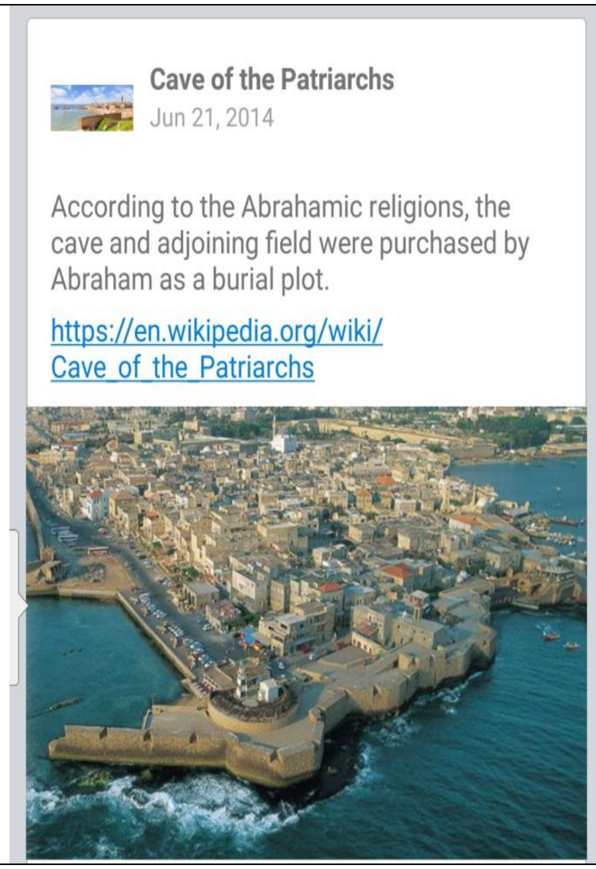


Figure 24. Location-based second result

4 **Scenario 4: Search by captuing images**:
Query: “user takes a picture for the dom of the rock - alaqsa” as input.

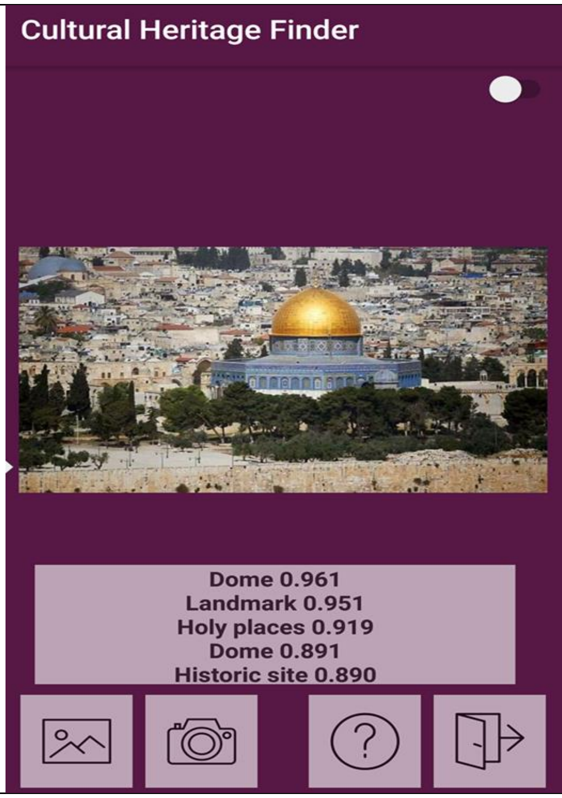


Figure 25. Query-by-example query

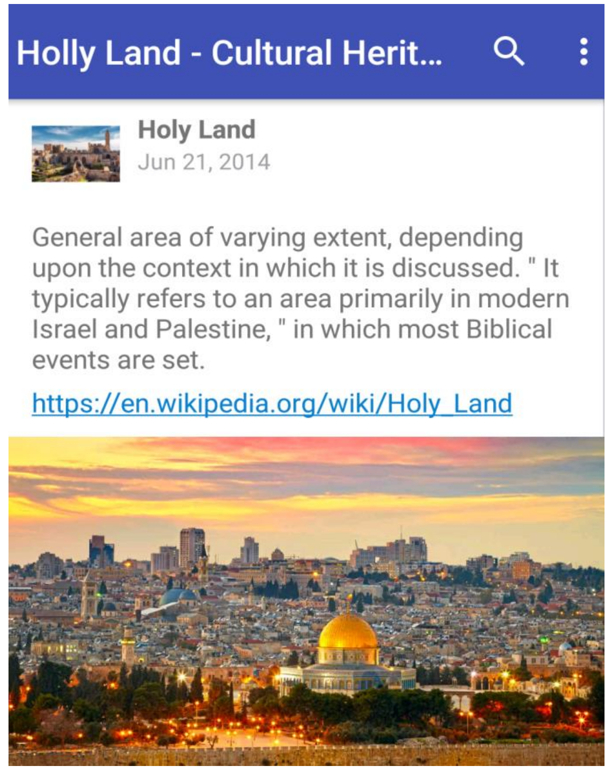


Figure 26. Query-by-example query results – result 1

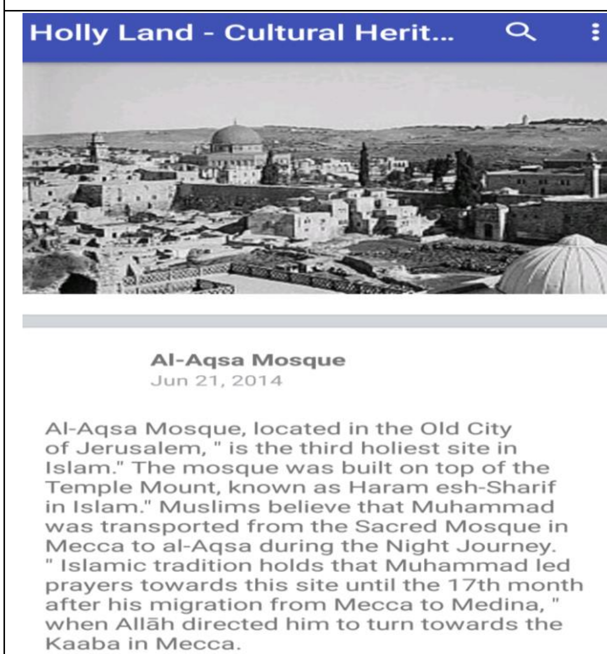


Figure 27. Query-by-example query results – result 2

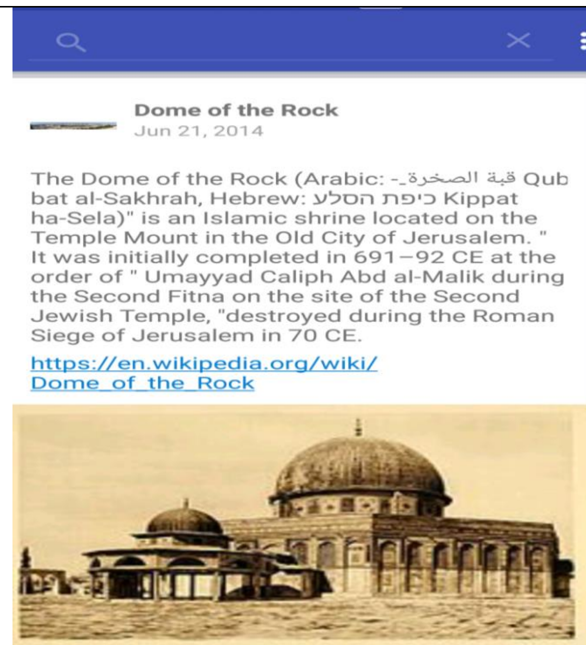


Figure 28. Query-by-example query results – result 3

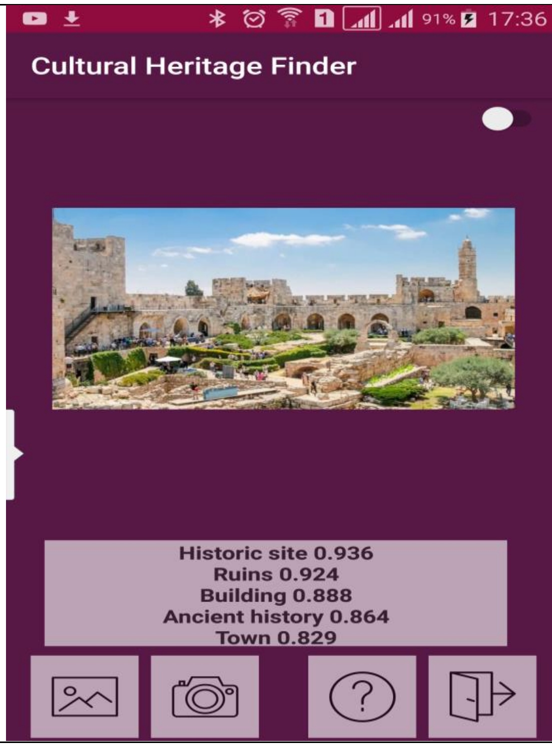


Figure 29. Query-by-example query analysis results

Figure 30. Query-by-example query results – result 2

To test and evaluate the quality of our system's prototype for the cultural heritage of the Holy Land area, we used the Black Box testing methodology, including checklists. The checklists were designed with clear and approved elements and distributed to three groups of users to examine the application by the following categories: experts in cultural heritage field, namely five persons from the Ministry of Tourism and Antiquities and five experts in information technology field and one hundred users that used different types of mobile devices such as, (different screen size, different operating system versions, etc.), where each group of participants were asked to evaluate the results of the recommendations and the data retrieve within the evaluation scale from 1 to 5. The black box test was evaluated in the project as follows: Functional Requirements Testing, Functional Testing, Usability Testing, Performance Testing and Security Testing.

Our checklists used with different items to test and evaluate the black box. The Functional requirements test is used to verify that the tracing between requirements and testing has improved. Function Requirement test (Verify that mobile based-application grants users to search by using keywords, by using device location, by using image capture by mobile camera, by using image in mobile gallery, allow end users to installing the application successfully, Uninstalled successfully, Grants user to accept calls when it’s running and continue from the same point after the call ended.), The Functional (Test is used to verify that the system functions and search methods were evaluated (search using query phrases, searching across the site location and cultural heritage surrounding it, searching using images taken through cameras or image upload from gallery). Test all the required fields should be validated. Test the sign fields should display for all the required fields. Test the mobile based-application should not display the error message for optional fields. Ensure maximum field length to ensure data is not trimmed.Confirm the function of the buttons. Privacy Policy should be available to users. Ensure that if any functionality fails, the user is redirected to a dedicated page. Ensure that an appropriate message appears that is not available for the network while the network cannot connect to the Internet or determine the location device. Test ease of installing the application while meeting all requirements. Ensure that the application restarts at the same point after the application crashes. Ensure that the application does not impede the ability to multitask the mobile device.), The Usability test (is used to measure the ease of use of the developed prototype, the ease of installing and compatibility with different types of mobile devices such as, (different screen size, different operating system versions, etc.), system compatibility and support for the proposed languages (Arabic, English, French and Hebrew) and compatibility with different versions of different devices and its appearance of data, elements and images clearly and understandable for users within the correct colors, fonts and effects. (Ensure that the contents of the application are displayed correctly in the mobile device. Ensure that the images shown are done correctly through the mobile device. Ensure that the fonts are usable through the mobile device. Ensure that the content of the pages is correct, without any spelling or grammatical errors in the application. Ensure that all fonts carry the same characteristics set as per requirements), Performance Test (Ensure performance and applicability under different loading conditions, Ensuring the components of the device support the work of the application within the proposed work functions of the system, determining application failures and not appropriate for the characteristics and features of the mobile device, Ensure that the new version of the application does not have a negative impact on the performance of the mobile device in response speed), Finally, Security Test (Ensure that no critical information appears during error messages. Ensure that application request user permission when used mobile camera or device location. Ensure that application does not use any service or other application without request user permission. Ensure that the application does not provide any important information about the application, server or database, and only display the appropriate error page. Ensure that SQL injection attacks are handled well during the application. Ensure that "Source Code" option is disabled and not visible to the user).

Table 2 Black box testing results

	IT Experts		**Users**		**CH Experts**	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Function Requirement test	4.4	0.8944272	3.95	0.7436601	4	0.7071068
Functional Test	4.2	0.83666	3.72	0.9329003	4	0.7071068
Usability Test	4.2	0.83666	4.18	0.7160498	4.4	0.5477226

Performance Test	4.4	0. 54772255	3.88	0.9020739	4.2	0.83666
Security Test	4.4	0.5477226	3.99	0.7848954	4.4	0.5477226

The results show that the cultural heritage recommendation system based on mobile applications for holy land has provided results that express the satisfaction of user requirements. The means for 5 IT experts, 5 Cultural Heritage experts and 100 evaluators were 4.32, 4.2 and 3.944, and the standard deviation of IT experts, Cultural heritage experts and normal users was 0.778867, 0.669264 and 0.815916, respectively.

By looking at the test results of the black box, we can see that the test elements of the system's functionality by the three groups are as follows: IT experts, cultural heritage experts and normal users, 4.32, 4.2, 3.944, respectively where the results indicate that the mobile based application provides very good and satisfactory precision results, in spite of the incompleteness of the dataset of Holy-Land cultural heritage ontology which led to a decline in the results according to normal users.

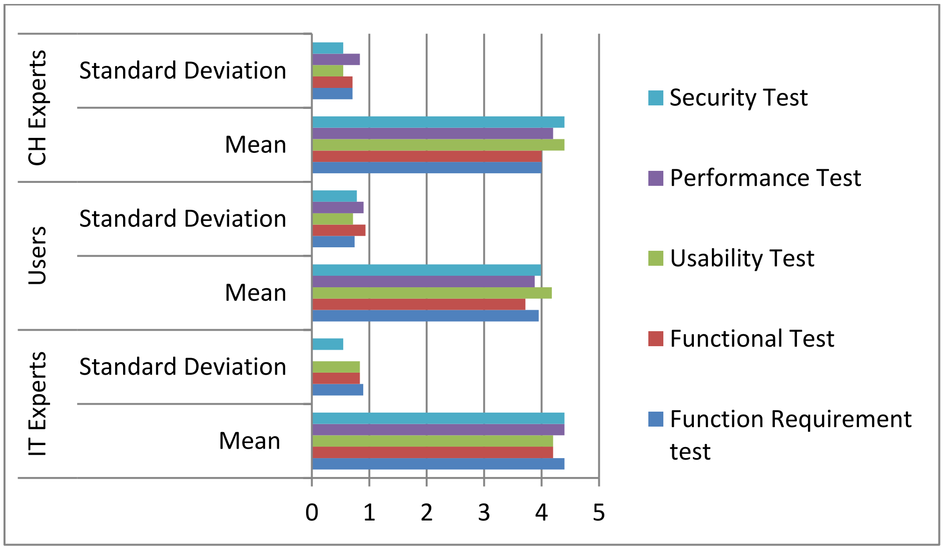


Figure 31 Black box testing results

Next, we compare the results of the mobile-based cultural heritage of the Holy-Land area with a tourism heritage recommendation mobile-based application and ontology [55].

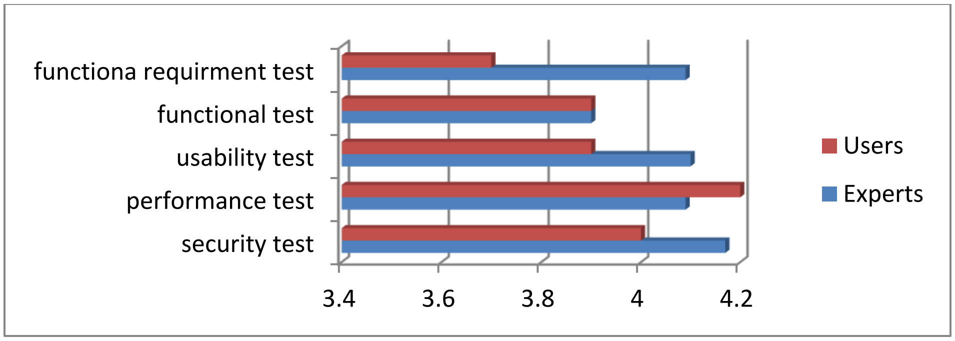


Figure 32 Black box testing results tourism heritage recommendation

The comparison between our system and the other system shows that our mobile-based application was able to yield more promising results across the different categories of the black box test. We argue that the main reasons behind this improvement lies in the fact that we have offered additional search features to users and enabled them to acquire the desired information using a variety of options. In addition, we argue that the construction of the proposed ontology has led to additional enhancements of the system, namely considering the semantic search capability of the text-based search methodology. Moreover, we believe that the incorporation of machine learning techniques to extract and recognize objects from images has also assisted users in further understanding the content of the images that they capture and share.

5.3 Summary

In this chapter, we discussed the experiments that we have displayed to validate the competence and the achievement of the proposed mobile-based cultural heritage mobile recommendation application for the holy land. In addition, we have compared the produced results by our system with other state-of-the-art systems in an attempt to evaluate the quality of our developed prototype and test the main features that are offered to end users.

CHAPTER SIX - CONCLUSIONS AND FUTURE WORK

In this chapter we summarized our proposed approach for building Cultural Heritage Information Retrieval (CHIR) system, we discussed its findings and contributions, points out the limitations and challenges that we faced in building the proposed system. In addition, it outlines the future extensions for the current version of our proposed system. The chapter separated into two sections. Section 6.1 presents a discussion of the contribution for our research work and highlights the techniques/approaches that we utilize in the proposed system. Section 6.2 discusses the future works and the other challenges that we plan to address the upcoming mobile- based application updates.

6.1 Conclusions

In this thesis, we developed mobile-based application to retrieval cultural heritage information with the aim of birding semantic gap and bypassing identical keywords between user queries and relevant documents in the domain of cultural heritage of the Holy-Land and support it with four languages. By doing this, our proposed approach improves user's satisfaction in searching for the cultural heritage data of the Holy-Land, draws the best results that match their needs and answer questions related to the cultural heritage of Holy-Land. To achieve this goal, we worked on constructing ontology for the Holy-Land and support it with four languages, where we could not get a pre-designed ontology in this area, and then we worked on building the proposed application and enriching it with three types of search and querying approaches. They are: 1) traditional search using keywords that are then processed by algorithms through the application to retrieve information and address the semantic link to terminology, 2) search based on location site where the user can search for places near the user's location where all the places and historical events are displayed within a specific range of the user's location, and 3) search by example where users are able to search using images taken through mobile camera device, where analysis through the use of machine learning technology that enables the extraction of objects and text detection and recognition from the image input, retrieve information about the image content captured . The prototype developed in its current version was tested using the technology of the black box test in five categories and (function requirement test, functional test, usability test, performance test, security test) where a questionnaire was given to users from different user groups and they (experts in CH, experts in IT, normal users) were then asked to fill out the questionnaire to get their comments about the prototype for the mobile-based application. We used the same testing methodology that was also used in a similar system in order to be able to match our results with those that were produced and reported on the similar system. By comparing our system with other systems in the field of cultural heritage, we have noticed that our work includes a set of features where the technique of searching for the contents of images, whether text or elements using machine learning, has been introduced, as well as searching within a specific geographical spot to obtain information related to the cultural heritage of that geographical spot and building a science Presence of the Holy-Land, enriching it with relevant information, and supporting it in a group of languages related to the inhabitants of this land.

6.2 Future Work

In this research, we wished-for (proposed) a multi-lingual semantics-based cultural heritage mobile recommender system that support users multifunctional textual search; searching based on location, as well as using image capturing for text recognition and object recognition. We reformulate users' queries in an attempt to improve the quality of the returned search results and increase people's satisfaction about cultural heritage search engines. This system provides more recommended results for users. The initial results of this mobile-based application indicate that the use of mixed methods such as ontology, site-based services and recommendations has been successfully carried out through the recommendations of the currently developed prototype; which have been found satisfactory to the information requirements of the users concerned in the cultural heritage of the Holy-Land area. For future work, we need to make training for machine learning to enhance the image capturing results in our system and support of more languages. Additionally, we plan to further extend the current ontology with additional semantically-relevant concepts about Palestine's cultural heritage events and places. when we tested our recommendation system in the cultural heritage field, we noted some need to develop the system to work within areas where internet service does not exist, we will work to enable the user to temporarily store data before the internet service interrupted, as well as store users behavior and event logs on the system during the Internet interruption in rules Private database and enable the user, when connected to the Internet, to re-sync those records. Also we found some archaeological areas in Palestine that contain huge heritage sites and events in the same area such as Jerusalem city, so we will work to enable the user to determine the distance as dynamic parameter to obtain more information about the cultural heritage related to his need.

6.3 Summary

At the end of this chapter, Palestine today, has a special ontology in the field of cultural heritage, and it has a system of recommendations that provides information for users who are interested in this field, with many features that can be offered and available on their mobile devices. We are pleased to present this unique work that has led to the construction of the ontology of the Holy-Land and the construction of a mobile application to retrieve the cultural heritage data of the Holy-Land using various research techniques and implement machine learning technology during research and provide recommendations to users to obtain their satisfaction while using our application. We will work on developing the recommendation system with more technologies that we discusses, such as working during the Internet outage period, as well as adaptation to provide more relevant and appropriate recommendations for the person and the possibility to change the distance during research by defining the site and enriching it with more information and concepts related to the cultural heritage of the Holy-Land.

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APPENDIX

Questionnaire for evaluating the proposed application

Questionnaire goals:

Through mobile devices, visitors can access reliable content related to cultural heritage sites around the world. The user can search for any desired site, and details related to it will be provided in a timely and elegant interface. Users can express their information needs by using keywords to describe their information needs. Or by using the current location (to recover historical places and events related to the place where the visitor is located), taking into account the network's availability. In addition, it allows users to take photos and upload them online to be shared with their friends enabling them analyze the photos based on their captions.

Information about evaluating user, (select your category):

1. IT experts.
2. Cultural heritage experts.
3. Normal users.

Note: Rating (1, 2, 3, 4, 5), where (1) is bad, and (5) Excellent.

In this questionnaire, we present the program test components related to our proposed mobile-based application within the following basic elements:

	Types of Test Cases	
1	Function Requirement test	Ranking (1,2,3,4,5)
	Verify that mobile based-application grants users to search by using keywords	

	Verify that mobile based-application grants users to search by using device location	
	Verify that mobile based-application grants users to search by using image capture by camera	
	Verify that mobile based-application grants users to search by using image in gallery	
	Verify that mobile based-application have to be Installed successfully.	
	Verify that mobile based-application have to be Uninstalled successfully.	
	Verify that mobile based-application grants user to accept calls when it's running and continue from the same point after the call ended.	
	Verify that users able to receive messages when mobile based-application is running and resume from the same point.	
	Verify that mobile based-application push proper error message to the users when memory of device is low.	
	Verify that mobile based-application provide alert when battery is low for the user.	
	Verify that mobile based-application not spend more battery.	
	Verify that mobile based-application should run when connecting the charger.	
2	Functional Test	Ranking (1,2,3,4,5)

	Verify that mobile based-application provide information related to keywords that used in search	
	Verify that mobile based-application provide information related to device location	
	Verify that mobile based-application provide information related to image captured that takin by mobile camera	
	Verify that application provide information related to image upload from gallery	
	Test all the required fields should be validated.	
	Test the sign fields should display for all the required fields.	
	Test the mobile based-application should not display the error message for none required fields.	
	Ensure maximum field length to ensure data is not trimmed.	
	Confirm the function of the buttons	
	Privacy Policy should be available to users.	
	Ensure that if any functionality fails, the user is redirected to a dedicated page.	
	Ensure that an appropriate message appears, if network not available or disconnected to the Internet or the location device not active.	
	Test ease of installing the application while meeting all requirements.	
	Make sure the desired page scroll bar appears.	

	Ensure that the application resumes at the same point after the application failures.	
	Ensure that the application does not impede the ability to multitask the mobile device.	
3	Usability Test	Ranking (1,2,3,4,5)
	Ensure that the contents of the application are displayed correctly in the mobile device.	
	Ensure that the images shown are done correctly through the mobile device.	
	Ensure that the fonts are usable through the mobile device.	
	Ensure that the content of the pages is correct, without any spelling or grammatical errors in the application	
	Ensure that all fonts carry the same characteristics set as per requirements.	
	Ensure text alignment via application screens	
	Ensure that the error messages are correct and that there are no spelling or grammatical errors and that they are appropriate for the event.	
	Check tool tip text for every field in the app.	
	Ensure the alignment of fields properly.	
	Ensure that there is adequate space between field labels, columns, rows, and error messages.	
	Ensure that all buttons are in standard size and format.	

	Ensure the application is working correctly with different resolutions, such as(640 x 480, 600 x 800 etc.)	
	Ensure that the user can operate the system without any problems or failures.	
4	Performance Test	Ranking (1,2,3,4,5)
	Ensure performance and applicability under different loading conditions	
	Ensuring the components of the device support the work of the application within the proposed work functions.	
	Determining application failures and not appropriate for the characteristics and features of the mobile device	
	Ensure that the new version of the application does not have a negative impact on the performance of the mobile device in response speed	
5	Security Test	Ranking (1,2,3,4,5)
	Ensure that no critical information shows during error messages.	
	Ensure that application request end user permission when used mobile camera or device location	
	Ensure that application does not use any services or other applications without request user permission.	

	Ensure that the application does not provide any important information about the application, server or database, and only display the appropriate error page.	
	Ensure that application cookies do not store passwords.	
	Ensure that SQL injection attacks are handled well during the application.	
	Ensure that "Source Code" option is disabled and not visible to the user.	

الملخص

تأثر قطاع التراث الثقافي والخدمات السياحية المرتبطة به بشكل ملحوظ بتقدم الإنترنت والتطور في مجال الهواتف الذكية. وركزت الرسالة على افتقار الانظمة الالكترونية التقليدية في مجال التراث الثقافي إلى القدرة على تكييف سلوكها مع التفضيلات والمهام والاهتمامات وغيرها من الميزات التي يطلبها المستخدمون. حيث تم اقتراح تصميم نظام توصية في التراث الثقافي متعدد اللغات، قائم على الدقة ومصادر دلالات المعاني وموجه نحو التراث الثقافي لفلسطين. وذلك بهدف تسهيل وصول المستخدمين إلى محتوى التراث الثقافي من خلال تزويدهم بوظائف بحث متعددة. حيث يتيح النظام للمستخدم البحث عن مواقع التراث الثقافي أو الموضوعات ذات العلاقة عبر واجهة مخصصة؛ حيث يأخذ النظام استعلامًا معينًا كمدخل ويسترجع جميع وثائق التراث الثقافي ذات الصلة بناء على تشابهها دلالي المعنى. حيث يقوم النظام بمعالجة استفسارات المستخدمين من خلال استخدام تقنيات معالجة اللغة الطبيعية والأنطولوجيا متعددة اللغات وغيرها من مقاييس المصطلحات. إضافة الى توفير خيار البحث باستخدام الموقع الحالي (لاستعادة الأماكن والأحداث التاريخية المرتبطة بالمكان الذي يوجد فيه الزائر)، مع الأخذ بعين الاعتبار توفر الاتصال بالانترنت. أيضا، يتيح النظام للمستخدمين التقاط الصور وتحميلها على الإنترنت لمشاركتها مع أصدقائهم كما يتيح لهم تحليل الصور بإستخدام تقنية تعلم الآلة وذلك لإستخراج النصوص بناء على محتويات الصور الملتقطة (الأوصاف النصية المرتبطة بكل صورة وغيرها من المعلومات ذات الصلة بالسياق). علاوة على ذلك، يهدف النظام المقترح إلى التكيف مع تفضيلات المستخدم واحتياجاته من معلومات؛ لإضفاء الطابع الشخصي على تجربتهم من جهة، وتقديم تفاعل أكثر فعالية وكفاءة من جهة أخرى. وقد تم تطوير نموذج أولي للنظام المقترح وتم اختباره باستخدام أجهزة محمولة تعمل من خلال أنظمة تشغيل Android ومعجم دلالات معاني الكلمات الذي تم إنشاؤه يدويًا (أطلق عليه الآن اسم Holly Land Ontology) والذي تم إثرائه من خلال ربطه بـ Art &

وقاموس المرادفات الدلالية DBpedia حول معلومات التراث الثقافي. عند مقارنة نظامنا Architecture بأنظمة آخرى في هذا المجال، وجدنا أن نظامنا يوفر ميزات إضافية للمستخدمين. إن تطبيق تقنيات التعلم الآلي لاستخراج الكيانات من الصور والتعرف عليها قد ساعد أيضًا المستخدمين على فهم محتوى الصور التي التقطوها، وتوفير معجم دلالات المعاني الخاص بالارض المقدسة الذي تم إنشأه من قبلنا هو الأول الذي يعالج معلومات التراث الثقافي في فلسطين (الأرض المقدسة).