Analysis of Semantic Technologies for Ethiopic Church Manuscript, Art and Music

By

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ABSTRACT

Information seeking, gathering and processing has become the sixth sense of individuals, organizations, consortia and nations. Today, information is represented and accessed in myriad forms across range of domain areas and cultural horizons. For most, the World Wide Web (WWW) is considered as a single and indispensable source of information. Currently, keyword-based search engines allow sifting through loads of information in WWW so as to arrive at relevant query results. However, substantial amount of irrelevant query results chiefly due to blind information representation scheme to culture, specialized domain of interest, and natural language datasets sees through the birth semantic web. Semantic web advocates exploiting conceptual hierarchies, relationships defined within and associated logical axioms for a more focused set of query results. It employs ontologies for expediting the knowledge representation endeavor in this respect.

Various studies conducted in the context of semantic web show that variations in spectrum of culture and domain of interest affect the way information is represented and accessed. In the same vein, it has been noted that devising and formalizing ontology for capturing the extremities of knowledge confined in such avenues is an exalted challenge. To this end, we have chosen Ethiopic Church Manuscript, Art and Music domain area so as to investigate and analyze issues surrounding the representation of Ethiopic concepts within the context of semantic web. Salient ontologies namely- manuscript, art, music, feast, time, date and number ontologies- are abstracted after careful scrutiny of related ontologies and usage of suitable ontology development methodology. Acquisition and digitization of representative data samples for classes of concepts and provision of a model for storage and retrieval of information related to the domain of interest, is also entertained. Furthermore, an experiment for evaluation of ontologies abstracted and model proposed is conducted by implementing a form-based semantic search engine and comparison of query results with that of keyword-based search engines. Initial results shows that the devised ontologies aloft the searching process in the domain area as well as unveil set aside issues, specific to Ethiopic concepts within the context of semantic web.

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CHAPTER ONE

1. Introduction

1.1 Background

Information acquisition, organization and extraction are part and passel of the daily activities of human beings; spanning from the early era of hunter-pray to the latest era of information age. At Stone Age, mankind keeps track of the information about seasons and surroundings while agriculture and industry era are marked by the acquisition and extraction of seed and market opportunity information respectively. Today, nations, consortia and individuals are becoming heavily dependant on information than ever. Recent boom in Information Communication Technology, especially that of WWW, made possible to have up-to-date, accessible and most of all readily available information. The effect of information is felt in growth of businesses, security of countries and success of individuals in the world we lived in now.

Information is defined as data that has been given meaning by way of relational connections while knowledge is an appropriate collection of information, such that it is useful in defining meaning and abstraction [1 p. 33]. The existence of tacit and explicit knowledge from myriad information sources and an increased demand on usage of information calls for representation and management of knowledge.

In the past, inscriptions, hardcopies and oral narratives are practiced in representing knowledge that is mainly tailored for human consumption. However, issues related to scalability, consistency and availability were stumbling blocks in the aforementioned schemes. The inception of computers shade a light on the way knowledge is represented and managed in this respect. Unprecedented efficiency in retrieval, extraction and storage of information and an ability to represent knowledge beyond human consumption made computers as a widely accepted medium for knowledge representation and management. Associated with representation of knowledge in computers various schemes were proposed. Logic and rule based approaches, frames and semantic networks were entertained in early

1970's and 1980's [2]. Also, the availability of programming languages fuels modeling, actualizing and benchmarking the various knowledge representation schemes discovered. However, problems in acquiring relevant information, extracting information contextually and accessing information across heterogeneous and unstructured sources are still challenges to be resolved.

Retrieval and extraction of information is a subject of information retrieval. Information retrieval is defined as a field concerned with the structure, analysis, organization, storage, searching, and retrieval of information [3]. Information retrieval was almost synonymous to text retrieval; particularly with popularity of World Wide Web. But, increased interest in information extraction especially in that of question answering, user profiling, web structuring, multilingual and multimedia content retrieval led focus back to the original objectives of information retrieval [3].

Information extraction is dealt in different veins within different domains. In library systems use of controlled vocabulary, catalogues, on subject matter is practiced while retrieval of information in WWW[1] is mainly handled by search engines. Search engines establish several mechanisms to locate an answer for a given query in a web. Traditional search engines employ keywords and thesaurus for indexing and retrieving documents while goal based search engines [4] make use of "common sense", domain knowledge categorization and natural language templates. Concept or semantic based search move the quest of retrieving and extracting information in a web a step further by practicing concept relationships and hierarchies.

When it come to practical issues each of the above methods have weakness and strengths in extracting information. Obvious disadvantages of cataloguing are restriction of user query in limited set of catalogue words and scalability. However, cataloguing has an inherent advantage in query formulation: unambiguous and free of misspelled queries. Traditional search engines cater problems in catalogue based searching by providing keyword and thesaurus based approach. However, disparity in query formulation has profound effect on

[1] World Wide Web

retrieving relevant information. For instance, searching for length of Blue Nile River can be approached "What is the length of Blue Nile River?" versus "length + Blue Nile + River". The later approach is better in finding relevant results as it is closer to keyword approach used by traditional search engines. Also, discrepancies in document representation, blind usage of keywords in documents and human centric retrieval aggravate the problem of locating relevant documents. Traditional search engines are also lame in addressing cultural differences in information representation and machine to machine information retrieval. For instance in the previous example documents that contain "Abay", which is the local name of Blue Nile, will not be at all considered even if some document contain length of Blue Nile encoded with the name "Abay". To resolve the above issues, concept or semantic based search engines are used in lieu of traditional search engines. The foundations of semantic search engines were laid on principles and building blocks of semantic web.

As envisioned by Tim Berners-Lee, the semantic web represents the next iteration of the World Wide Web, in which networked computers will be able to extract "meaning" (or, more precisely, meaningful data) from each other instead of crude strings of code [5]. The aim of semantic web is to pave a way for locating, organizing, sharing and accessing information for machines as humans do. Semantic search engines employ ontologies and logic for concept representation of a document and solve problems related with traditional search engines [6].

1.2 Thesis Statement

Variation across domains of interest and cultures in representing knowledge is a major challenge for information retrieval [3], [7]. A prosaic example can be seeking an answer for query "□□□□□□ □□ □□□□□ □□□ □□□" on a web. In this scenario, understanding the semantics of the query in relation to feast, music, and person concepts within the church domain is a requirement. Also for further inferencing, knowing the date on which the feast "□□□□□" commemorated, the 19th day of the month, is relevant vis-à-vis pointing out relationships with related concepts.

Retrieving information across information spaces, reasoning based on conceptual meanings and acquiring relevant information are the major issues on such avenues. Traditional search

engines are oblivious in extracting and presenting alike requirements. Consequently, demand for a platform that is capable of processing information in meaningful and machine processable format is imminent.

Semantic web, the next iteration of the current web, promise to cater problems in connection with the current searching mechanisms by laying a ground for conceptual hierarchies and relationships within domain area [8]. Ontologies are used to expedite the aforementioned goals of semantic web.

Devising an ontology that accurately represent conceptual relationships and hierarchies in a given domain area is a challenge [8]. This is largely due to unbounded growth of knowledge and lack of common perspective on a given knowledge by domain experts. A number of researches were conducted across myriad application domains and cultural spectrums [9]-[11] in the context of semantic web to investigate such issues. However, to this date, no work is done in relation to Ethiopic based concepts.

With machine to machine communication at the door [8], Ethiopic concepts need to be evaluated against the existing semantic technologies. Thus, modeling and fostering ontology by taking Ethiopic church manuscript, art and music as a domain of interest as well as evaluation of semantic query results in contrast to traditional keyword engines are the main concern of the research.

1.3 Rationale

Colossal progress in representation of information within the context of semantic web on one hand and plethora of cultural artifacts in Ethiopic church manuscript and media on the other hand propel the motivation of this research. The impetus of the research is also expressed in investigating how Ethiopic concepts fit in the next generation of searching platform-the semantic web. Moreover, modeling and formalizing common Ethiopic concepts incorporated in Ethiopian culture as a whole, like that of time and calendar, on the web is a huge drive.

Aside from the above motivations, a subtle amount of researches conducted in connection with semantic technology for Ethiopic contents/concepts is a major force for conducting the research. The following are supplementary rationales for the research

- Modeling an ontology for Ethiopic church manuscript and media concepts.
- Providing an avenue for a full fledged Ethiopic semantic search engines and software agents
- Creating a means for acquisition, preservation and fact finding tasks in the area of Ethiopic church manuscript and media
- Leading to standardization of concepts related with Ethiopic church and media area, for instance in the area of time and calendar to be used by agents
- Paving a way for knowledge reusability and sharing among domain experts
- Minimizing knowledge gap by providing information in meaningful and scalable way on the web
- Promoting cultural values of Ethiopia, act as bridge for resurrection of knowledge and artifacts that are close to be extinct or internalized by certain individuals

1.4 Objectives

The main objective of the research is to model, formalize and analyze Ethiopic concepts in the context of semantic web. For actualizing the above objective Ethiopic church manuscript and media is chosen as there is ample information in the domain. Also, analysis of the quality of semantic queries results for concepts defined within Ethiopic content in semantic web context is entertained. The following are additional objectives:

- Identification, abstraction and formalization of appropriate ontology for Ethiopic church manuscripts, art and music
- Analysis of related and supportive concepts from other cultures and domain areas as to extend or surrogate if the domain area concepts align
- Development of a model for storing and later retrieval of an Ethiopic church manuscripts, art and music in the context of web semantics.

- Implementation of a multi-criteria semantic query with the aim of discovering relationships, relevancy and comparisons among different instances and classes.
- Accusation, alignment and maintenance of rudimentary information for the domain area
- Evaluation of the existing semantic web technologies in relation to Ethiopic church manuscripts, art and music.
- Shallow comparison of semantic queries with non semantic queries results
- Identification of major future extensions to be performed in the area of semantic web

1.5 Scope

This section details the boundary and demarcation under which the research is conducted. The research is performed considering the following limitations:

- Focus on mainly modeling of Ethiopic church manuscript and media with extension of related concepts. The research doesn't at all try to model the vast and versatile traditions of Ethiopic church heritage.
- Limited sets of data is used for querying and presenting information as there is scarcity in digital format of data in the area
- Effectiveness of query result is only considered and performance issues related to response time are differed for a mere reason of avoiding bias in usage of third party search engines
- As much as possible, conceptual relationships and hierarchies are used instead of language specific characteristics to avoid bias in using third party search engines and to focus on the objectives of the research
- Only Unicode formatted data are considered for processing queries as there is no support for non standard encodings in the layer of semantic web
- A standalone system working on a single web domain is used for experimental purposes.
- Artwork merely considers paintings in the context of Ethiopic church.

1.6 Contribution

Consortiums, stakeholders, individuals and software agents use semantic technology for a number of purposes. Researchers from the domain of library science, especially those in philology can make use of it in locating information; balance between cataloguing and keyword searching. Historians can run different semantic query instances across concepts to investigate relationships between historical periods. Software agents can exploit knowledge defined and abstracted for purposes of presenting relationships among a range of manuscripts. Individuals can query and synthesize information to know knowledge horizons in the area of Ethiopic church manuscripts, art and music. Artists can gather and analyze information in relation to eras and style of Ethiopian art periods. The following are some scenarios where the research can be applied:

- Studying the relationships among manuscripts. For example, a priest or a theologian might be interested with the relationships between "□□□□ □□□□" and "□□□□ □□□□", a historian might query for relationships between manuscripts of origin from □□□□ and □□□, an artist might be interested with relationship between artworks in the period of 18th and 10th centaury.
- In academics, relationships between manuscripts and media within Ethiopia, and ontologies from other cultures can be compared in search of discovering some new relationships between arts, music and manuscripts in other countries that were not known before. For example, relationship between music modes in Ethiopia and Sudan or Ethiopia and Egypt can be investigated
- Based on facts (instances) contained in the ontology assertion can be done. For example, a historian or user might want to find specific answer for the manuscript at 18th centaury, in specific place and written using particular material that contain a particular artwork.
- Based on arbitrary textual description for inference. For example, an individual or an agent might be interested on some specific answers without knowing the detail of the classes and instances. Like "□□□□□ □□□□ □□□□ □□□□□□" or "□□ □□□ □□□ □□ □□□□□□"
- Can be used as a base for further study of Literature and arts in Ethiopia

1.7 Thesis organization

This section preview document organization and a highlight of the chapters contained in the research. Chapter 1 of the document examines background, problem formalism, objectives, rationale and contributions of the research. State of the art on semantic web, ontology development methodologies and related issues are scrutinized in Chapter 2. Also, this chapter focuses on defining terminologies and elaborating laid upon theories and facts to avoid ambiguities in the coming chapters. Chapter 3 draws attention to assessing researches conducted in the area of manuscript, art and music besides addressing the merits and demerits of related researches. Chapter 4 put into perspective architectures adopted for solving the research theme. Here, explanation of models provided for retrieval and storage of data as well as constraints and flow of process is presented. Formalization of the problem solution, salient activities performed in ontology development and ontologies churned out of this process is discussed in Chapter 5 of the document. Chapter 6 details issues surrounding on the implementation of a prototype developed for the model proposed and formalism presented in chapter 5 and 4 respectively. Chapter 7 of the document portrays the experiment conducted as a proof of theory. The chapter spans steps followed in conducting, obtaining and analyzing results in the experiment in the context of Ethiopic church manuscripts and media. Finally, Chapter 7 gives concluding remarks and future work dimension of the research.

CHAPTER TWO

2. Semantic web and related issues state of the art

The state of the art related with semantic web technologies, ontologies and accompanying issues are put forward in this chapter. The chapter also set in perspective basic concepts, theories, and terminologies used in the research.

2.1 Knowledge representation

Catering a way for representing information and building knowledge on the web is one of the fundamental goals of semantic web. Information is a data with an attached meaning, in contrast knowledge deals with purpose and competence to add reasoning capabilities on a data. Existence of information from numerous sources, heterogeneity in structure of information and a need for conceiving knowledge from the existing sources asks for a scheme in representing knowledge.

Knowledge representation across spectrums of domains is a subject of various studies [2]. Disciplines like cognitive science and artificial intelligence were driving forces in formalizing knowledge representation activities as they thrive in modeling human thinking process and representation of knowledge in computers respectively. Semantic web on the other hand longs on formulating and extending a mechanism for describing and representing data on the current web for the purposes machine processing and inferencing. Tandem with knowledge representation endeavors, commencement of mathematical logic and knowledge representation languages fan the flames of knowledge representation endeavors.

Knowledge representation is concerned on an abstraction and interpretation of real world knowledge using formal theories and reasoning procedures [2]. Formal theories allow abstraction of knowledge in an explicit manner for a domain area besides paving a way for declarative and deductive reasoning. For instance, taking the following assertions “St. Gabriel is an Angel” and “All angles are spirits”, and asking the query “beings that are spirits?” need interpretation, analysis and representation of the earlier assertions. Here, a

formal and explicit method in representing the assertions, a platform for connecting and associating the various concepts in the assertions and most of all a spell to carry out reasoning is a prerequisite.

2.2 Ontology and Logic

Semantic web make use of ontologies and logic to affect representation, storage and retrieval of knowledge on the web. Ontologies are preferred way of knowledge representation in semantic web as they facilitate representation of machine accessible information formally and explicitly with sound reasoning support for a domain of interest. Ontology is an "explicit and formal specification of a shared conceptualization for a domain of interest" [12]. The formal dimension of ontologies make sure of avoiding misunderstandings and ambiguous meanings, the use of formal languages for specification besides creating a room for automatic reasoning and common consensus. Explicit dimension of ontologies on the other hand deals with extremities of knowledge capturing process, types of concepts used and the constraints on their use, for the domain of interest. Also, shared dimension facilitates consensual knowledge that is a knowledge accepted by group of individuals.

Associated with formal specification, logic has been used immensely in computers. Logic assists interpretation and association of entities which in turn have a knock on effect of reasoning/inferencing, a requirement in semantic web. Reasoning/ inferencing is a way of reaching a solution given a set of assertions Logic provides deductive and procedural reasoning. The former reasoning technique uses premises and their relationships in order to reach a solution while the later use series of conditions and rules to arrive at a decision. Also, rise of knowledge representation languages and a firm theoretical ground for refutation in logic made possible actualization of ontologies in computers.

Mathematically, an ontology (O) is a set of concepts (S_C) in domain of interest, a lexicon (L) containing a set of signs (L_C) and a relation (L_R) among concepts. Also, a taxonomy (H) defining hierarchical relationship in-between concepts and a set of binary relations for specifying pairs of concepts U(D, R), a set of axioms(A_K) is used.[1 p. 55].

A family of logic that supports abstraction of ontologies with reasoning support are First Order Logic (FOL) and Description Logic (DL)[1 p. 70]. FOL make use of constants for representing concepts (S_C), unary predicates (L_C) for modeling properties, binary predicates(L_R) in abstracting relationship between concepts and well formed formulae(WFF) for logical structuring of conceptualization(A_K). But, lack of a built-in structure for representing concepts and efficiency of proof procedures make FOL less preferable for representing knowledge in relation to semantic web.

Description Logic (DL) a subset of FOL with a special restriction imposed on it. It consists of a set of unary predicate symbols(L_C) that are used to denote concept names , set of binary relations(L_R) that are used to denote role names and a recursive definition(A_K) for defining concept terms from concept names and role names using constructors. DL is a preferred method of knowledge representation for semantic web as it provides structures and abstractions for modeling ontologies and pertinent principles for efficient reasoning tailored for large source of data [1 p.54].

2.3 Ontology development process

Designing, modeling and developing ontologies requires methodologies alike science disciplines. Basically, methodologies for ontology are conceived from knowledge engineering applications, ontology sets and artificial intelligence. Salient methodologies and activities performed within are previewed in this section.

Cyc [13] a methodology from artificial intelligence, is one of the early methodologies in knowledge representation. It involves manual gathering and encoding of knowledge, construction of new knowledge primarily by making use natural languages and lastly acquiring new knowledge using tools.

Skeletal Methodology [14], based on previous knowledge engineering application, propose a four phased methodology. Definition of purpose of the ontology, building the ontology using either of the top-down, bottom up or middle out approaches, evaluation of the ontology build and documentation are the accompanying phases. Here, top-down approach advocates

generic to specific concept building while bottom up approach uses otherwise. Also, middle out approach identifies major concepts and works towards narrowing the concepts to specific terms.

TOVE [15], a methodology that uses first order logic, propose identification of scenarios and competency questions followed by extraction of main concepts, properties, relations and axioms. Competency questions are presented using natural languages and are used to extract relevant information from knowledge sources. Information is then extracted form the gathered answers sets and is formalized using first order logic.

KACTUS [16], a knowledge engineering application methodology, propose the abstraction of ontologies form knowledge bases. Specification of application, preliminary design to model top level ontological categories and ontology structuring and alignment are the major steps in KACTUS.

METHONTOLOGY [17], from Artificial Intelligence, is a methodology for building ontologies either from scratch, reusing other ontologies as they are, or by a process of reengineering them. Identification of development process, building of a life cycle evolving prototype and pinning down techniques for carrying out each of these activities are the major steps in METHONTOLOGY. The methodology includes identification of the ontology development process, a life cycle based on evolving prototypes and particular techniques to carry out each activity. The ontology development process identifies which tasks should be performed when building ontologies (scheduling, control, quality assurance, specification, knowledge acquisition, conceptualization, integration, formalization, implementation, evaluation, maintenance, and documentation and configuration management). The life cycle identifies the stages through which the ontology passes during its lifetime, as well as the interdependencies with the life cycle of other ontologies. Finally, the methodology specifies the techniques used in each activity, the products that each activity outputs and how they have to be evaluated.

The On-To-Knowledge methodology, from knowledge engineering, [18 pp. 34-42] involves feasibly study and requirement gathering, formulation of competency questions, identification of potentially reusable ontologies, design, refinement, evaluation and maintenance of ontology phases.

The ontology development process can be summarized as follows(Table 2-1) [19],

Activity	Description
Specification	identification of propose and scope of the ontology
Conceptualization	description of conceptual models and the ontology that should be built
Formalization	transformation of conceptual description to formal model
Implementation	actualization of the formal model using knowledge representation language
Maintenance	updates and corrects the implemented ontology
knowledge acquisition	techniques for acquiring knowledge either by using elicitation or referring biographies
Documentation	documentation procedures and rules for implementation as well as performing documentation process
Evaluation	technical evaluation of ontology build
Reuse	procedures for reuse and integration with other ontologies

Table 2-1 summary of activities in various methodologies

2.4 Ontology Languages

A number of knowledge representation languages are devised in liaison with knowledge formalizations and representations for computers. KIF [20] and Ontolingua [21] are two notable knowledge representation languages that exploit first order logic formalism. Deficiencies in inferencing power and limitation of expressiveness in connection to using first order logic stirs sighting of LOOM [22] and FLogic[23]. These language practices the use of procedural rules for inferencing on top of first order logic. Increased presence and peculiar features, semi-structured and heterogeneous information, of the web draw attention

to invention of knowledge representation languages for the web. SHOE [24] curbs the drawback of HTML [25] by augmenting ontological markup, rules and frame logic. Inefficiency in separating data from presentation, difficulty in exchanging information ramified adoption of XML [26]. SHOE armed with XML capabilities gave birth to XOL [27]; a language which have the strength of XML and SHOE.

Standardization effort by W3C sees the adoption Resource Description Framework (RDF) [28]; semantic network based language for describing resources. Later extension of RDF for addressing data type definitions and incorporating frame-based primitives set up RDFS [29]. Initiatives form DARPA and European IST project sees DAML [30] and OIL [31] to be incepted. Use of DL and automatic classification of concepts through the use of inferencing are the main features of OIL and DAML that further the quest of knowledge representation formalism on the web. Joint committee of the US and EU lay ground later for DAML + OIL. Considering the strength of RDF, OIL and DAML w3c adopted a standard ontology language for the web- the Web Ontology Language (OWL) [32].

2.5 Semantic web technologies

For most the web is an indispensable source of information. It is a place where one can find vast and rich information sets on diversified issues. However the success of the web, finding information that worth its salt is not something done easily. Representation of information primarily tailored for human consumption, inability in separating data from meaning, and deprivation of inferencing capabilities are major caveats daring a resolution in the current web. As an example, finding information related to hotel and travel fares for a tourist on a tour to “Laliblea” requires analysis, synthesis and interpretation of information from travel, hotel and tour web pages. Also, requirements in comprehending information encoded in natural language aggravate the pursuit of finding relevant information. Publishing, accessing and combining information in machine processable format averts the aforementioned problems. Such a scheme facilitates logical reasoning, sharing and reusability of information. The next iteration of the web, semantic web, advocates in advancing the above issues. Semantic technologies search topics, concepts, associations spanning a large number of sources to provide an exalted solution for a given question.

Semantic web is an evolving extension of the WWW in which web content can be expressed not only in natural language, but also in a form that can be read and used by software agents, thus permitting them to find, share and integrate information more easily [5]. It is a vision on imposing intelligence on computes in finding, sharing and combining data so as to arrive at relevant solution sets. The following are aims of the semantic web [1 p. 16-18]:

- Organization of knowledge in conceptual spaces according to its meaning.
- Usage of automated tools to support maintenance by checking for inconsistencies and extracting new knowledge.
- Replacement of keyword-based search by query answering: requested knowledge will be retrieved, extracted, and presented in a human friendly way.
- Query answering over several documents will be supported.

Thus, semantic web technologies sponsors not only use of raw information, but also constellations of information for knowledge processing and creation of new set of knowledge based on existing ones. It also asks for representation of knowledge in a machine processable format for making possible commitments lacking in the current web

2.6 Elements of the semantic web

One of the fundamental visions of semantic web is creating a platform for making use of the data in WWW for both humans and machines. To actualize this vision and cater problems related to the current web a convention for reconciling syntax and structure, a way to express, locate and relate data items, and an avenue for standardized vocabularies is a requirement. An architecture or standard satisfying the aforementioned issues is in place. The architecture imposes use of structured collection of information, logic and rules for automated inferencing. The following section briefly describe the major blocks of the architecture

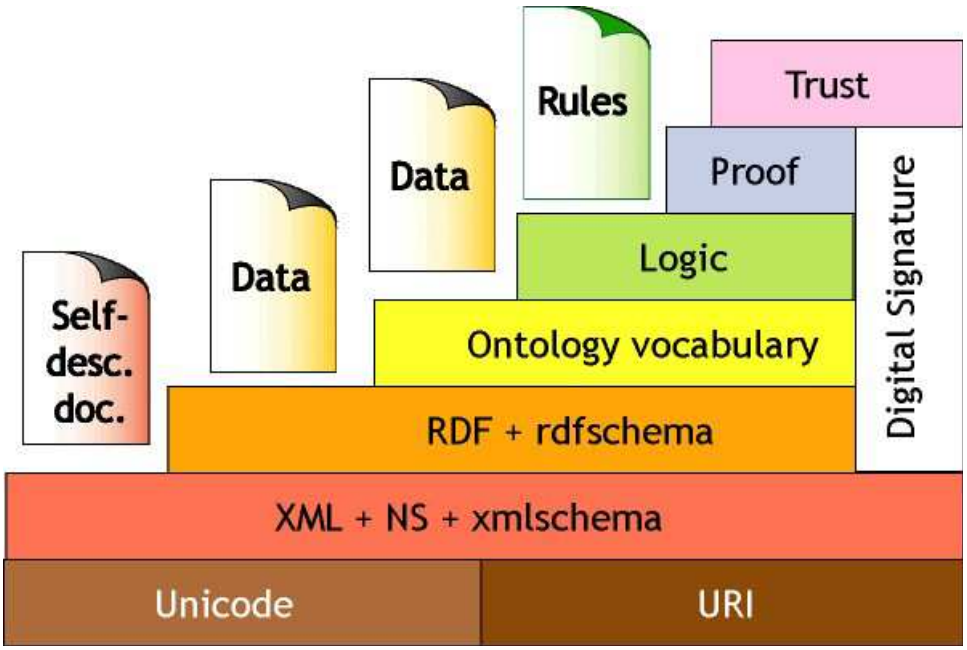

Figure 2-1 a layered architecture of semantic web

As shown in Figure 2-1,Unicode provides a unique number for every character without discrimination of platforms, programs and languages [33]. Unique identification of resources across the web is established by a Uniform Resource Identifier (URI) [25]. Syntactic and semantic structure of documents is ascertained by XML [26] while restriction of structure and content of elements contained within XML documents is constrained by XML Schema. RDF [28] lay a ground for expressing data models; resources and their relationships on top of XML. Besides, vocabularies for describing properties, classes and their relationship are facilitated by RDF Schema [29]. Further, definition of domain specific terms and their relationships on top of RDFS sees the use of ontology vocabularies. Consistency and correctness of datasets employed for logical reasoning are handled by the logic layer while steps for proof of data are explicitly handled by the proof layer. A means for provision mechanisms for authentication of the trustworthiness of data, agents and services is handled by the trust layer.

2.7 Semantic web frameworks and search engines

Search engines aid in sifting loads of information to locate an answer for a given query. Traditional search engines primarily make use of keyword frequency and link analysis in document while semantic search engines manipulate conceptual relationships and hierarchies

among documents for acquiring relevant information. Frameworks for realization semantic web layer and query languages capable of exploiting conceptual relationships and hierarchies are perquisites for the actualization semantic search engines.

Inception of query languages such as RQL [34], SeRQL [35] and the W3C recommendation SPARQL [36] enable traversing, locating and extracting information in the context of semantic web. Also Jena [37], a framework for the implementation of semantic web recommendations, provides utilities to extract data from and write to RDF graphs. Jena provides an abstract model for representing RDF triples, SPARQL implementation, support for classes of ontology languages and persistent/in-memory storage. Sesame [38], another notable framework in the arena, is an RDF Schema-based repository and querying facility. It supports RQL, SeRQL and SPARQL languages besides providing inferencing and persistent storage for large quantities of RDF and RDF schema data.

Availability of the theoretical and practical facets of the semantic web set the driving way for the design semantic search engines. Actualization of semantic search engines is entertained either by augmenting the traditional search engines with semantic notions or use of semantically annotated documents [1 p. 196]. The former method uses Latent Semantic Indexing (LSI)-imposing semantic association among keywords of a document- while the later method practice use of RDF, RDFS and ontologies for documents annotation. A glimpse of LIS is exhibited in Google while semantic search engines like Swoogle [39], TAP [40], Corese [41], SemSearch [42], QuizRDF [43] make use of semantically annotated documents and ranking algorithm similar to that of traditional search engines.

CHAPTER THREE

3. Related work

3.1 Culture and semantic web

Culture is the integrated pattern of human knowledge, belief, and behavior that depends on the capacity for learning and transmitting knowledge to succeeding generations[2].Inherent nature of cultural variation across range of demography determines the way information is perceived and accepted among parties. Also, expressive power of the symbolic structure used inside a culture put in perspective the way information is processed and assembled. Thus, in light of these issues the way searching, presenting and interpreting information is done for a domain of interest is a problem that cries out loud for a solution.

Semantic web sets a ground to trace meaning and knowledge organization across time and cultures through the use of mapping theories [5]. Various studies [9] [10] conducted for exchanging and integrating information across continuum of cultures in the semantic web show that narrowing the information disparity is a daunting yet doable task. Researches like CIDOC-CRM [45] provide definitions and a formal structure for describing the implicit and explicit concepts and relationships used in cultural heritage documentation. However, representing intricacies of cultural values calls for a close scrutiny of pattern of activities and symbolic structure employed in the cultural boundary.

Ethiopia, a country with vibrant and diverse cultural values is an exalted candidate for such cultural representations. According to [46], religion and other belief systems are often integral to culture of a society and in this respect Ethiopian church is considered as a constituted custodian of the nation's culture [47].

3.2 Ethiopic language and the web

Ethiopic, "the name given by western scholars to the language in which the Christian literature of Ethiopia has been preserved" [48 p. 47], is writing system rooted out of the

[2] Marriam Webster Dictionary definition

Semitic scripts. Ge'ez, Amharic and Tigrinya are the three major languages that use the writing system at a large scale [49]. The writing system essentially employs one character per syllable exploiting a repertoire of 410 symbols, numerals and punctuation marks. Today, despite disparity in encoding standards, presence of Ethiopic based content on the web is an emerging phenomenon.

It has been observed analysis, synthesis and interpretation of meanings encoded in natural languages is a daring problem associated with the current representation of information on the WWW; Ethiopic contents are no exception. A number of studies [50]- [52] are conducted in addressing languages specific issues related to Ethiopic; however, investigating whether Ethiopic is addressed in the semantic web is an issue yet to be resolved.

3.3 Ethiopic manuscripts, art, music and related concepts

Many scholars consider that the most distinctive attainment of Ethiopian culture lies in the vast collection of manuscript, compiled and preserved in the monasteries and churches that embody the national literary tradition [53]. The term manuscript has multiple definitions in multiple domains. A manuscript is any document that is written by hand, as opposed to being printed or reproduced in some other way[3]. In publishing and academic contexts a manuscript is a text submitted to the publisher or printer in preparation for publication while in library science it is defined as any hand-written item in the collections of a library or an archive. All these definitions agree on one point, that a manuscript is a form of writing.

Ethiopia as a hub of ancient civilizations and has a long record of writing practices. The country was able to record its history and preserve its own heritage that includes religion, astrology, traditional medicine, philosophy, politics, law, economic and diplomacy. Religion lies at the very core of Ethiopian civilization and the Ethiopian Church has been not only the storehouse of the national culture but also a propagator; instrumental in shaping and molding Ethiopian literature and art[54].

[3] Marriam Webster Dictionary definition

In liaison with artworks, Ethiopian church has had a rationale for the veneration of artworks as it is manifested in carving rocks, making caves, and catacombs. [53 pp 100-102]. With the exception of a few ancient rock carving or drawings which depict both human and animal scenes, Ethiopian art is virtually wholly ecclesiastic; characterized by biblical themes and figures. The paintings and pictures found in various manuscripts and on the walls in churches are also used to afford the viewer a moral lesson and religious instruction [53 p. 100].

Related to Ethiopic church music, St. Yared, an Ethiopian Scholar and hymnologist, guided by a spirit incepted the three unique modes of Ethiopian church music namely: Geez, Araray and Ezil. Theses modes are used in relation to seasons of worships, services of the church, feast and fasting periods by the church of Ethiopia [55 pp 17- 23].

Time divisions of the day, feasts and fasting periods play an integral role in Ethiopic church in relation to church services and worship. The Ethiopic church and Ethiopia as a country in general , is governed by 13 months with each 30 days except the 13^{th} which is 5 or 6 based on leap year calculations [56 pp. 21-26]. The time of the day is divided into 7 blocks accompanying a worship service for each division [53 pp 82]. Days of the year are also associated with feasts that are celebrated yearly, monthly, weekly and daily [53 pp 92].

The complex relationship among manuscripts, art, music, feasts and time in Ethiopic church and unabated grip of Ethiopic church in representing the nation culture makes Ethiopian Church manuscripts, art and music domain an ideal choice for analysis of Ethiopic concepts within the context pf semantic web.

3.4 Semantic web, manuscripts, art and music

A close inspection of related studies conducted in the area of manuscript, art and music within the context of semantic web and set aside issues specific to Ethiopic church manuscript and media are focal points of this section.

3.4.1 Manuscripts and semantic web

One of the essential tasks in formalism of ontologies is identification of terms and their relationships within the domain of interest. Such a task is amplified partly in making use of existing controlled vocabularies, taxonomies and thesaurus definitions in a domain of interest. In the past a number of novel taxonomies were proposed and exercised in such respects. Yahoo! and DMOZ [4]devise classification of web documents while MARC [58] and DDC [59] define terms and relationships among writing entities in libraries. Despite the fact that such classifications provide a spring board for development of ontologies in writing entities, limitations in expressive power of terms and spurious relationships between terms call forth additional efforts.

The incorporation of specialized markup languages on top of classification schemes stimulates the notation of knowledge representation in semantic web. TEI [60] employs specialized markup for a specification of digitized manuscripts in relation to archives, museums and libraries. The Dublin core [44], a specification for definition of cross domain metadata, aim in describing digital materials and composite media mediums like web pages by making use of fifteen high level markups. But, inherent problems in expressive power, generic representation format and lack of strict binding relationships in metadata and documents limit such efforts merely to high level exercise.

A more focused solution allotting higher importance to the notion of ontological commitments is used as next iteration. BibTex [61] a format and later ontology for formatting biographies, books and articles employ conceptual hierarchies and relationships. It defines main concepts, their relationship and axioms that guide the inferencing process. Also, specialized ontologies, like the W3c Bible ontology [62], underscores the importance of using ontologies in representing pertinent information of writing entities in the context of semantic web.

[4] http://www.dmoz.com

Studies have been conducted in relation to representing manuscripts across several cultural horizons and domain groups. A study on formalization and manipulation of Arnamagnæan manuscripts [9] - a manuscript primarily Icelandic but also Norwegian, Danish and Swedish- produce a manuscript semantic markup languages and an architecture for processing the data represented. The study spurs use of semantic web notions in representing manuscripts for bridging the gap in organizing, exploitation of manuscripts information sets. But, use of XML and rejection of use of RDF and ontology language proliferate problems contained in such schemes; lack of inferencing and expressive power. China Cultural Celebrities Manuscript Library (CCCML) [10] is an illustrious research in the area of manuscript and semantic web. It proposes an architecture that exploits ontologies, legacy databases and data integration techniques in search of providing sound information sets and representation of manuscripts.

The aforementioned researches put into perspective the techniques and methods for formalizing manuscripts in semantic web. However, the likelihood of representing Ethiopic church manuscript and related cultural values in number and quality using these schemes is far from positive. DDC, which is widely used in Ethiopia, has limitation in handling the unique features of Ethiopian manuscripts such as representing relationships with other concepts. For instance, according to the expert from National Archive and Library of Ethiopia (NALE) there is no viable way in representing relationships between verses in a book and music played for a given day. TEI, Dublin Core, BibTex are also insufficient in representing singled out features of Ethiopic church manuscripts such as conceptual relationships between and within music, feast, fast, seasons, day and artworks entities. CCCML, Arnamagnæan. and W3C bible ontology researches leave a lesson on how to represent cultural manuscripts adequately in relation to semantic web.

3.4.2 Art and semantic web

Art comprises of both physical and imaginary representation of the real world sceneries. It touches physical representation of objects like manuscripts, music and paintings as well as mental abstraction of entities [63]. In relation to artwork and semantic web the research

consider paintings as an artwork. The following section examines schemes adopted by studies in an endeavor for representing artworks in the context of semantic web.

Identification of art terms and relationships within has been an issue for range of domain applications. Museum and archives make use of cataloguing for sound while the web employs metadata for retrieval and exchange of artworks. However, cataloguing and metadata merely give attention to defining terms and fall behind in addressing relationships among terms- a semantic web requirement. Art and Architecture Thesaurus (AAT) [64] initiative from Getty Institute solves the above problem by defining art terms, facets of various artworks and their relationships. However, below par quality of thesaurus in representing knowledge in semantic web make endeavors like AAT only to be used as stepping stone for formalisms of art ontologies. Art-E-Fact research [65] abstracts an ontology that spans eighty concepts and their relationships for the purposes of defining a common platform and narrowing sporadic view of the domain experts. The research helps in gaining a common view of artworks, annotation and integration of art information and most all of sharing of perspectives among domain experts. Humor ontology [66] another notable work in area of paintings ascertain representation of multifaceted contemporary political cartons in context of Semantic web. It extends CIDOC CRM top level conceptual ontology model in order to represent a unique domain-specific features of contemporary graphical humor.

The above studies show the significance of exploiting and extending exiting thesauri and top level domain ontologies in addressing the many features of domain specific ontologies. Devising art ontology for Ethiopic church manuscript is no different in this respect. Ethiopic church artworks have an immense role in worship and services of the church that in turn affect the context and representation formalism. Also, specialized features in classification of artworks that is alien to classification scheme of the Geety and CIDOC CRM top level forces the abstraction art ontology for Ethiopic church. For instance, Ethiopic church artworks are classified mainly either with spiritual milestones like Christological cycle, Mariology cycle or a period different from other nations.

3.4.3 Music and semantic web

Rudimentary metadata and legacy databases are employed in commercial search engines like Yahoo!, Google et. al for representation of musical data. Substantial amount of irrelevant information and usage of proprietary metadata are chief problems related with such schemes. MusicBrainz, a vocabulary based representation scheme, curb the aforementioned problems by linking and sharing musical data on artists, albums and tracks information. Vocabularies provide common terms and shallow relationships among terms for sharing information. Standardization of MusicBrainz vocabulary sees the birth of Music Ontology Specification by the W3C [67]. The ontology addresses the identification of main concepts and relationships for describing music (i.e. artists, albums and tracks) on the Semantic Web.

As discussed in section 3.1 Ethiopic church music has unique relationship with manuscripts, feasts, fasting periods and seasons. This special feature is omitted in the MusicBrainz specification that calls for extension of the ontology for the domain area. Also, the ontology is primarily tailored toward western musical genres which are insignificant in the context of Ethiopic church manuscript and media. Thus, a way to accommodate Ethiopic church music mode and their corresponding features is a work to be done.

3.4.4 Time and semantic web

One of the fundamental issues lacking in the current web and addressed in semantic web is the definition of primitive data types for uniform data exchange and manipulation. The XML Schema layer of the semantic web arm semantic web with predefined primitive and user defined data types [69]. Data types sets the constraints under which members of a certain concepts adhere to and plays a significant role in analysis of conceptual relationships, definition of axioms and rule based reasoning. For instance, age property in judicial ontology can be encoded as having a data type of number whose value range form 0 to 18 for juveniles or otherwise. Such a constraint has a magnitude in excluding the irrelevant data from the relevant ones.

XML Schema provides date and time data type on top of others for manipulation of Gregorian dates. It provides syntactic and functional means for accessing the various components of a Gregorian date and time. For instance, one can define a data type xsd:gday for defining a range value of a certain concepts in languages like OWL. In relation to temporal concepts such as seasons, era, and the likes an ontology specification [68] by the W3C plays a pivotal role. The ontology exploits established mathematical notion of interval and instances with datetime and duration descriptors. Even if XML Schema and time ontology stir representation of time conscious values succinctly luck of support for calendar systems outside Gregorian calendar pause a serious problem. XML Schema fail to provide a primitives for Islamic, Hebrew, Ethiopic, Chinese and similar calendar schemes. The ramification of such a deficiency in XML Schema is reflected on the time ontology as it uses Gregorian calendar scheme as descriptors.

Ethiopic church uses calendar scheme that is wildly different from the Gregorian date. Numerical notation, number of days in months, and number of months in year are some salient problems to mention. The above problems are discussed in the example below, Table 3-1.

Scenario	**Problem with XML Schema**
··· · ·····	No feasible way in representing Ethiopic numerals
···· · 1999	No means for representing the 13th month
13 4 199	No means for representing the 13th month
13 7 199	No means of knowing the 13th month has a date less than or equal to 6
···· · ·····	No notion of knowing whether the date lies in one of the seasons of the Ethiopic church.

Table 3-1 Problems with XML Schema date time in relation to Ethiopic date and time

The above scenarios show both the XML schema and time ontology need to be augmented to support Ethiopic church date/time needs.

3.4.5 Other related issues and Semantic web

Ethiopic church manuscripts, art and music have a special bond with concepts that are not at all addressed in studies conducted in the domain of interest. For instance, querying the information hub for "ⷪⷪⷪⷪⷪⷪ ⷪⷪ ⷪⷪⷪⷪⷪ ⷪⷪⷪⷪ" and "ⷪⷪⷪⷪ ⷪⷪⷪⷪⷪ ⷪⷪⷪⷪ", "ⷪⷪⷪⷪⷪ ⷪⷪⷪⷪⷪ ⷪⷪ" calls exploitation and analysis of conceptual relationship among feast, fast and season concepts within the domain of interest. Feasts, fasting periods, church architecture and creature concepts and their relationship have a significant impact on the endeavor of representing knowledge in the domain of area. Alienating the above concepts in the previous example will make impossible to retrieve information on persons that are born at 19th- feast St. Gabriel celebrated -of the month feast, books that are read at the period of fasting Nineveh and Music that are sung during winter seasons. Thus, putting aside such concepts not only make the knowledge representation effort incomplete but also unusable.

Ethiopic church bear a classification scheme for feasts, fasts, seasons, creatures and church architecture [53 pp. 21-24, 72-82] [56 pp. 59-70] [57 pp. 43-44, 258-268]. These schemes provide definition and identification of conceptual hierarchies in ontology design. Relationships and axioms of the conceptual hierarchies are augmented by lectionaries and sanctorials that provide essential relationships with manuscripts, art and music [56 p. 87].

3.5 Semantic web and Ethiopic Concepts

Even if a number of researches were done in the area of Ethiopic content information retrieval very little or no study were done in the area of semantic web. Most of the studies [50]-[52], revolved around addressing issues related with components of keyword-based search engines. Such works can be used as a catalyst in advancement of semantic based search engines as semantic web is the next iteration of the current web. However, the fact semantic search is beyond keyword-based search leave researches conducted in the area of semantic web at its barebones.

CHAPTER FOUR

4. Proposed model for storage and retrieval

4.1 Overview

Model of the system depicts major components and schemes of communication and collaboration employed for a given theoretical solution. It also spans responsibility of the components involved and the constraints under which the model remain functional. Description and scrutiny of a theoretical solution for interfacing, querying, storing, aligning and presenting information in the context of semantic web is the essence this chapter. A theoretical model for storage and retrieval of information within semantic web as well as comparison of query results computed by traditional search engines are part of objectives of the research. Additionally, the model is projected to provide a test bed for evaluation of the designed ontologies by the domain experts. In light of these objectives, an abstraction that facilitates independent keyword and semantic based search is proposed.

Keyword based search side of the model cover components for interfacing with keyword-based search engines and their way of communication and division of responsibly. It is chiefly forwarded in order to expedite comparison of query results returned by keyword-based search engines with that of semantic search engines. This part of the model devise an interaction scheme that consider results returned form keyword-based search engine with exclusion of crawling, indexing and ranking tasks to the internal components of traditional search engines.

The semantic search face of the model is stirred for laying out theoretical ground for abstractions required in performing semantic search. It augments Jena [37] framework by adding components for tracking user responses on the relevancy of the query results and client query formulation. Jena arms the proposed semantic search abstraction with query processing and optimization, knowledge inferencing and RDF store manipulation. Jena is chosen primarily as it implements all recommendation of the semantic web and considered a standard in the arena. The semantic search side of the model also reflects on use of

ontologies and RDF store encoded in Ethiopic and presentation of in a single web domain for retrieval of query results.

4.2 Constraints and Assumptions

Constraints and assumptions of a model describe theoretical and practical limitations, set ups and expectations for the model remain operational. The following are constrains and assumptions of the proposed model:

- Controlled set of data (web pages) from a single web domain/repository is used as there are no Ethiopic based web pages that are semantically annotated with the ontology devised in the research
- Omission of language specific issues except rudimentary operations such as character by character matching for a mere reason of avoiding bias. Currently commercial keyword-based search engines don't support language specific issues for Ethiopic contents.
- Traditional keyword search model is used only for showing the quality of query results and as a test bed for evaluation of the ontologies by the domain experts.

4.3 Components of the proposed model

This section details description of components involved in the proposed model. Client, Ethiopic Query Interface (EQI), Web Container (WC), User Response Handler (URH), User Response Store (URS), Ethiopic Query Builder (EQB), Page Store (PS), Keyword Based Search Agent (KBSA), Result Presenter (RP) and Jena Semantic Framework Query Manager (JSFQM) are the components of the proposed model. The following figure, Figure 4-1, layouts the above components in the proposed model.

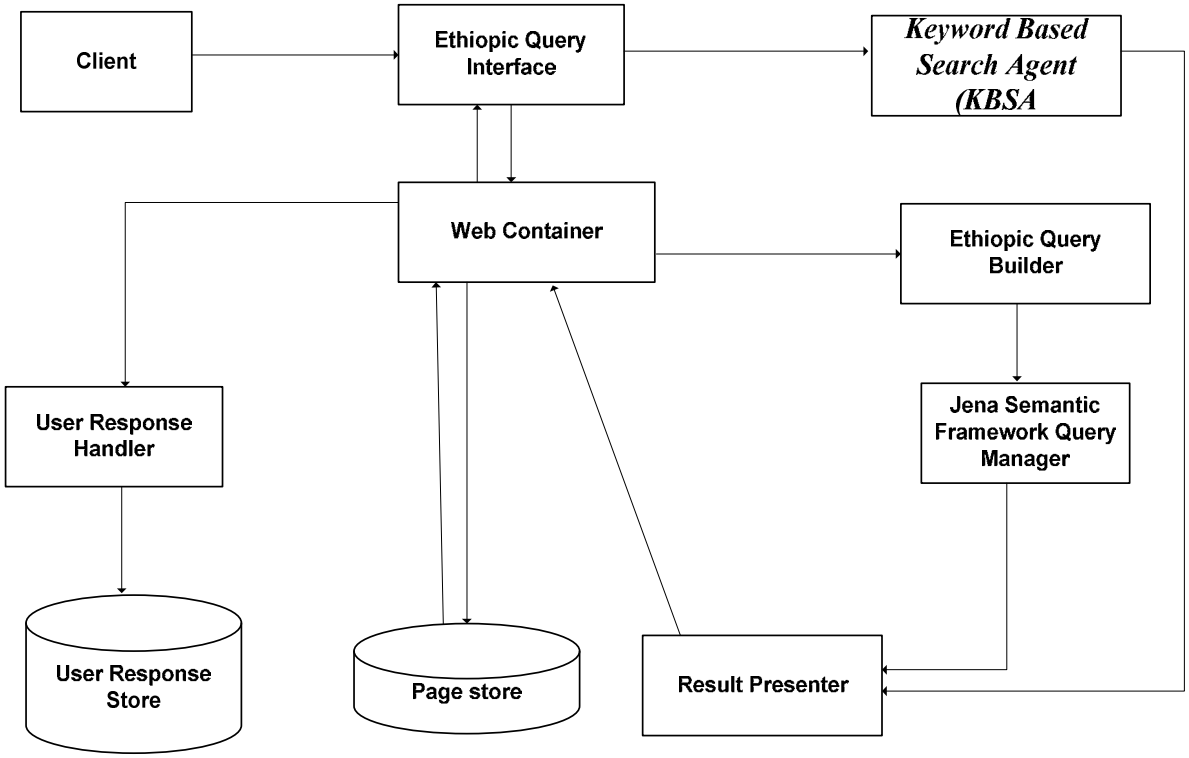

Figure 4-1 Proposed model

Responsibility and functionalities of the components herewith are presented as follows:

1. ***Client Component***: an abstraction of an information seeker- a person, legacy system or a machine code-that formulates queries for requesting the web repository besides interacting with the returned results. It interacts with EQI to issue queries encoded with Ethiopic language.
2. ***Ethiopic Query Interface (EQI)***: a component that allows a client to input an Ethiopic language based queries for further processing by WC. The component is responsible in presenting and aligning Ethiopic Unicode Character ranges accurately and correctly to the client. It accepts character inputs, currently ASCII codes, from keyboard and returns the corresponding Unicode representation in Ethiopic. The component is also responsible for handling Ethiopic character typing conventions for ASCII based keyboards. For instance, handling diacritic mark, character insertion and numeral representations are the chief tasks of this component.

3. ***Web Container (WC)***: is responsible in handling HTTP requests and presenting response to and from peer component. It is also responsible in dispatching data represented in Ethiopic language appropriately to the receiving end component.
4. ***User Response Handler (URH)***: after query results are presented to the client, the client can put a feedback on the relevancy query results. A component responsible for tracking client ratings on return query results is URH. It accepts client responses from the WC then parse and format the gathered responses according to the specifications of RS. Additionally, URH acts as a temporary bucket for collecting query results, query target and their corresponding rating till the data is committed to RS.
5. ***Keyword Based Search Agent (KBSA)***: facilitate acquiring query results form third party keyword search components by issuing query statement, number of results to be returned, checkpoints for query results returned and specification of protocols imposed for communication. It accept queries dispatched form the client through the WC, format and reassemble queries and dispatch a request to third party keyword-based search components. Furthermore, processing of returned results form third party keyword search components and presenting it to RP is the responsibly of KBSA.
6. ***Result Presenter (RP)***: it is a component which embeds rating features, pagination and display formats appropriate to the client type, HTML or XML, for a query result returned by KBSA or JSFQM. The main purpose of RP is making sure user friendliness and ease of use in presenting query results returned by KBSA/JSFQM.
7. ***Ethiopic Query Builder (EQB)***: a component responsible in formulating SPARQL queries for inputs dispatched by EQI to be processed by JSFQM. EQB parses and perform conversion of Ethiopic language and church specific facets to appropriate XML Schema types. For instance, Ethiopic numerals and date data is converted to their corresponding XML Schema types at this stage for further processing.
8. ***Jena Semantic Framework Query Manager (JSFQM)***: embody components of Jena semantic framework for querying, inferencing and presenting query results by making use of the designed ontologies and RDF store.
9. ***Page Store (PS)***: a repository, preferably annotated with designed ontologies, of Ethiopic church manuscript, music and media web pages.

CHAPTER FIVE

5. Ontology formalism

5.1 Overview

Semantic web utilize ontologies as a preferred way of knowledge representation. Ontologies allow sharing and explicit formalization of knowledge for a domain of interest. Of the fundamental objectives of the research is to design an ontology that appropriately models the knowledge contained in Ethiopic church manuscripts, art and music domains of interest within semantic web. The study gives birth to eight ontology groups namely- Number, Date, Creature and Creator, Feast, Manuscript, Music, and Art- after applying an ontology development process methodology. The goal of this chapter is, therefore, to present in detail the ontologies formalized for Ethiopic church manuscripts, art and music domain areas in the context of the semantic web.

Discussion of ontology development methodology employed, related ontologies considered for elaboration of concepts as well as sample use cases and competency questions utilized for illustration of conceptual relationships for the domain of interest is presented and examined in this chapter.

5.2 Ontology formalism representation

OWL-DL a variant of OWL ontology language put in balance expressive power and inferencing complexity in a knowledge representation. Hence, definition of concepts, relationships within and identified axioms presented in this document make use of the OWL-DL ontology sub-language. The following terminologies are used in the methodology selected:

Concepts/Classes are major entities contained in the domain of interest. They are usually organized in taxonomies under an inheritance hierarchy. For instance, a writing entity may contain: *"books, pages, chapters, paragraphs and verses"* in a conceptual taxonomy.

Relations model associations between concepts of the domain. An example can be an inheritance association between chapters and pages. Verses are part of paragraphs and this is modeled using sub-class notations.

Instances used to capture individuals/elements of an ontology concept. For instance, "Deggua" or "New Testament" is an instance of a book.

Attributes/properties describe properties of instances and of concepts. For example, page number is a property of page.

Axioms are logical expressions that are always true and are normally used to specify constraints in the ontology. An example can be *"a verse contains a minimum of chapter and verse number properties"* or *"a book has always at least a single title"*.

5.3 Methodology

Various ontology development methodologies were proposed and are in use for formalizing a knowledge contained in a domain of interest. These proposed methodologies have very specific advantages and disadvantages for a range of situation at hand. While some are suited to situations when existing ontologies and domain application are presented others best fit a gradual development cycle starting from scratch. The research employs a methodology, METHONTOLOGY, which puts a balance between flexibility and reusability. We have chosen this methodology for the following reasons:

- It allows an evolutionary development approach for development of ontologies that has a value added advantage in this research work. Inherently the task of modeling ontologies for the domain area at hand asks for division of tasks due to vast and enormous knowledge contained in the arena.
- The methodology facilitates reuse of related ontologies in the domain area by other studies without further ado.
- It gives freedom in choosing the activities that are suitable for the domain area at hand. Unlike other ontology development methodologies, dropping some of the

activities defined in METHONTOLOGY is a possibility which makes it an ideal choice in such scenarios.

Along with the chosen development methodology, the following steps are exercised for formalization of ontologies in the domain area.

1. Specification of the purpose and scope of the ontology to be developed. Here, a high-level declaration of what the ontology will model and capture is stated.
2. Conceptualization, identification, elaboration and assimilation of domain concepts, relationships and axioms using:

- Competency questions for domain experts: Questions ranging from simple blind to relaxed and elaborated ones that are asked usually using Question and Answer type discussions and brain storming sessions.
- Literature reviews: review and assessment of studies conducted for identifying similar concepts and seeing if reusability can be possible besides pining down related concepts that are found in Ethiopic church literatures.
- Formal and Informal discussions: discussion of major concepts with peer deacons, priests and alike colleagues to clear the air in understanding the domain area in terms of computing domain expressions.

3. Formalization of identified concepts, relationships and axioms using notations.
4. Implementation of the formalized knowledge using the OWL ontology language.
5. Acquisition of sample instances for concepts from literatures and domain experts.
6. Review of the implemented ontology by domain experts and gather feedbacks.
7. Incorporation of new concepts, relationships and axioms vis-à-vis maintaining existing ones.
8. Documentation of the designed ontology.

Furthermore, the following tasks, as stated in the selected methodology, are performed for the conceptualization process in step 2:

- Building of glossary of terms, concepts and instances
- Building concept taxonomies

- Identifying ad hoc binary relation diagrams
- Building the concept dictionary
- Defining ad hoc binary relations in detail
- Defining instance attributes in detail
- Defining class attributes in detail
- Defining constants in detail
- Defining formal axioms
- Defining rules
- Defining instances

5.4 Ontology formalism

Ontologies formalized for the domain of interest using METHONTOLOGY ontology development methodology is presented in this section. In course of formalizing the ontologies discussed herewith literatures [56 – 57], [53], activities stated in step 2 of the methodology and the TopBraid Composer [70] ontology development workbench are employed. Specification and details of implementations and formalisms are attached in Appendix A and Appendix B respectively.

5.4.1 Number

XML Schema makes use of Arabic numbers in representing primitive data types for modeling various number types. The fact that Ethiopic languages uses numerals that are different from Arabic ones and the practice of Ethiopic numerals enormously in the church domain asks for formalization of Ethiopic numerals. Moreover, mixed usage of Arabic and Ethiopic numerals on some instances underlines the need of a formalization that glues the two representation schemes. The Number ontology is born for addressing these needs.

5.4.1.1 Conceptualization

Based on specification and fact-finding endeavors described in Appendix A section 1, we have identified the single concept, Number, for modeling XML Schema non-negative integer data type and the corresponding Ethiopic Numeral description. The Number concept is

further boosted by identification of attributes, as shown in Table 5-1, that describe relational sequence of instances.

Term	Type	Description
Number	Concept	Describes Arabic to Ethiopic numerals
Arabic number	Attribute	Represent Arabic non negative integer number for the corresponding Ethiopic Numerals
Ethiopian Number	Attribute	Represent Ethiopic numerals
Equal, greater and less than	Relation	Models relational sequence of numbers

Table 5-1 Summary of glossary of terms for Number conceptualization

The following axioms are identified in association with the above concepts

- An individual of Number has exactly one representation of Ethiopic Numeral
- An individual of Number has exactly one representation of Arabic Number
- Any Number concept is valid if and only if it is expressed using Arabic Number and Ethiopic Number instance attributes
- Greater than, less than and equal relations are transitive
- Equal is defined as symmetric and functional

5.4.1.2 Use case example

Citation of verse numbers by various manuscripts and date/time formats used in books that direct celebration of feasts. An example can be the numbering system employed in the Bible for verses, chapters, and page numbers, verse numbers like "፡፡ ፡፡፡", and date time data items like ፡፡/19 for representing the St. Gabriel feast celebration and ፡፡፡፡፡ for the Gregorian year 2006/2007.

5.4.2 Date/Time

Date and time representation are primitive data types defined in XML Schema. XML Schema allows representation and manipulation of Gregorian dates and times by providing facets for date/time related properties. However, the lack of support for Islamic, Hebrew, Ethiopic, and

other calendars puts a barrier in the quest of developing ontologies for domain areas that exploit these schemes. A classical example of Ethiopic date is found in book of Synaxry and the book of "• •" that dictate feast, fast and music mode used across the days of a year. These books use Ethiopic date/time based calculations for arriving at seasons, feast celebrations, Sabbath, fasting periods and musical orderings. Usage of Gregorian dates in such scenarios is not only inappropriate but also incomplete. For instance, the date "• • • • • •", which is fixed holiday for Ethiopic church, can lie between September 9-12 across year ranges which creates dilemma in knowledge representation and deepens complexity in the inferencing process. Thus, formalizing the discrepancy mentioned in Ethiopic date/time is the heart of this section.

5.4.2.1 Conceptualization

Conceptualization process commences with analysis of scenarios for the Ethiopic calendar and assimilation of date/time XML Schema. A specification (Appendix A and B section 2) that outline the various needs of Ethiopic date/time representation is used in this process. Table 5-2 details terms and relationships of the conceptualization

Term	Type	Description
Date/Time	Concept	Describes a date/time representation of Ethiopic calendar
Day	Attribute	Represent the days in a year for Ethiopic church
Day number in a year	Attribute	Represent
Gregorian date/time	Attribute	Ethiopic calendar corresponding date/time value of in Gregorian calendar
Hour	Attribute	Hour representation in a time. It run from 1-12
Less than, greater than, equal	Relation	Relation sequence discriminators for data/time classes
Minute	Attribute	Minute in a time. It run 1-59
Month	Attribute	Month number for Ethiopic calendar. It runs from 1-13
Month name	Attribute	13 names of Ethiopic calendar

Second	Attribute	Second in a time. It run from 1-59
Time scale	Attribute	Time scale for a date/time
Week	Attribute	Week number contained in year
Week Day	Attribute	Week days for a date. Monday-Sunday are appropriate classes
Year	Attribute	Year contained in a date

Table 5-3 Summary of glossary of terms for Date/Time conceptualization

After identification of the various facets associated with Ethiopic date, conceptual associations and instance attributes are churned out for modeling purposes. Number concepts outlined in section 5.4.1 are used for representing all numeral values associated with date/time representation. We have defined a date/time as an 11 valued function that spans day, month, year, month name, day of the year, weekday, week, time scale, second, minute and hour values. The following axioms are identified for Date/Time concepts

- Date/Time description is an 11 valued function that has a maximum of one day, month, year, month name, day of the year, weekday, week, time scale, second, minute and hour values
- All axioms in section 5.4.1 are applied as direct ramification of usage of Numbers
- Greater than, less than and equal relations are transitive
- Equal is defined as symmetric and functional
- All day values run from 1-30
- All month values run from 1-13

5.4.2.2 Use case example

Ethiopic church calendar has 13 months with 30 days each except for the 13th which has 5 or 6 [56 pp.21-26]. Moreover, the Ethiopic calendar uses a 12 hour time representations for the day. A typical example is the Ethiopian new millennium year, "፲፱ ፻ ፺ ፱ ፡ ፲ ፪" and the last date of the year before the new millennium of Ethiopia, "፲፱ ፻ ፺ ፰ ፡ ፳ ፱ ፡ ፲ ፪". Queries like the local saint born in Ethiopia at date "፲፱ ፻ ፺ ፱ ፡ ፲ ፫" require an appropriate date/time knowledge representation scheme.

5.4.3 Temporal time

Temporal time models topological temporal time concepts using intervals, instances and duration. The Ethiopic church defines and makes use of temporal time concepts abundantly. An illustration of temporal time in the Ethiopic church is found in musical seasons and epoch of years. According to [56 p. 73], the Ethiopic church uses 4 seasons inspired by St. Yared for worship and liturgical services. Also, each year is associated with one of the four Gospel writers [56 p. 22], St. Mark, St. Luke, St. John or St. Matthew. The W3C devised a Time ontology that addresses temporal concepts based on descriptors of duration and date/time representations, intervals and instances. Additionally, the W3C time ontology is extended and augmented with Ethiopic church temporal concepts and Date/Time notions for addressing needs of the domain area.

5.4.3.1 Conceptualization

Based on the specification and concepts gathered and trimmed for various temporal concepts (see Appendix A and B, section 3) defined in the Ethiopic church worship, Lectionaries and Sanctorials we have come up with salient temporal time concepts presented as follows (Table 5-3):

Term	Type	Description
Date time description	Concept	Describes a date/time representation of the Ethiopic calendar
Era	Concept	An interval marked by a certain duration of period. For instance, the era of art period or manuscript period
Event	Concept	Describes a happening of an event in history terms of duration. For example, the reign of King Menelik or the fall of Lalibela.
Season	Concept	Describe seasons of the Ethiopic church. These are Tsedey, Kiremet, Hagaye and Bega

Week commemorate	Concept	Week duration has a name in Ethiopic church especially for fasting periods. Week commemorate tells the name and interval details of a week. An example can be the weeks for the Great Lent are listed as "• • • •", "• • • • •" and the likes
Year commemorate	Concept	Describes the name of the year interval. Year commemorate can be John, Luke, Mark or Matthew.

Table 5-4 Summary of glossary of terms for Temporal Time conceptualization

In tandem with temporal time formalization, the following axioms are used:

- Date/Time description is an 11 valued structure that has maximum of one occurrence for day, month, year, day of the year, weekday, week, time zone, second, minute, hour values and associated unit type
- A Date/Time interval is a proper interval described by date/time descriptor
- All axioms from the W3C and Date/Time formalism described in 5.4.2 remain intact

5.4.3.2 Use case example

The year • • / 2000 commemorated for St. Mark while each Sunday in fasting period of Lent or Greatest Fast have specific names "• • • •", " • • • •", "• • • •", "• • • •", "• • • • • •", "• • • • •" and "• • • • •" [53 p.75] which are expressed using intervals. Moreover, seasons of musical period "• • •", "• • •", "• • •", "• • • •" [56 p. 73] are temporal concepts defined by date/time descriptions. In relation to retrieving information, one can query for verses of books that are read in a given season, for example "• • •". Here, knowing the time span for the specified season is a requirement for returning relevant results.

5.4.4 Creature and Creator

The mystery of creation is one of the pillars for faith in the Ethiopic church. The Ethiopic church uses a creature classification scheme depicted in scriptures unlike their biological counterparts. We have found out that the concept of creation has a huge magnitude of impact when it comes to abstracting feasts and associated manuscripts used in such occasions. For instance the creature St. Michael, an angel, has a specific relationship with feast of St. Michael, the day 12th of the month and book "• • • • • • • •". On top of these facts, Ethiopic church gives due respect for martyrs, and saints by defining odes and hagiographies. Hence, we have found that formalizing creature and creator concepts make the knowledge representation in the domain area more complete and representative.

5.4.4.1 Conceptualization

According to [57 pp.43-44], all creatures are created by God in order over six days; the first classification scheme in a way. We have taken this classification scheme boldly and decorate it with instance attributes as shown in Table 5-4 and 5-5.

Term	Type	Description
Creation	Concept	Describes all Creations in the church domain.
Creator	Concept	Describes creator class
First day creation	Concept	Classes of creatures in the first day of creation. These are Angel ,Fire, Light, Water, Wind, Darkness, Earth and The seven heavens
Second day creation	Concept	Describes classes of creatures created in the second day. Only a single class resides; Firmament
Third day creation	Concept	Describe classes of third day creatures namely: Trees, Grasses, Vegetation
Fourth day creation	Concept	Describes classes of creatures created in the fourth day. This includes Moon, Stars and the Sun

Fifth day creation	Concept	Describes classes of creatures created in the fifth day. This comprises of Creeping with breastbone, Flying birds animals and beasts and Moving with feet creatures
Six day creation	Concept	Describes classes of creatures created in the Sixth day. Human (Women, Man), Animals, Beasts, Birds and fowls are creatures in this category
Service	Concept	Tells about the profession or service of a human creature
Title	Concept	Tells about title endorsed by the church or secular organization for a creature
Birth date	Attribute	Birthday of a creature
Birth place	Attribute	Birth place of a creature
Country of birth	Attribute	Country of birth for a creature.
Dead	Attribute	Discriminator that tells whether a creature is dead or alive
Death date	Attribute	Death date for a creature
Death place	Attribute	Death place for a creature
Fallen	Attribute	Discriminator that tells if an angel has fallen or not
Given name	Attribute	Name given by the church for a creature
Last name	Attribute	Last name of a human creature
Local saint	Attribute	Discriminator for telling whether a saint is local or not
Name	Attribute	Name of a creature
Speaks language	Attribute	Spoken language by a creature
Writes language	Attribute	Models written languages for a creature

Table 5-5 Summary of glossary of terms for Creation/Creator conceptualization

Conceptual relation	Description
Served as	Associate a human creature with the service it perform/ed
Order of creation	Maps sequence of creation.

Table 5-6 Summary of conceptual relationships for Creation/Creator conceptualization

Formalization axioms for identified concepts and instance attributes are defined as follows:

- Creator and Creature instances can overlap
- A human creature have at least one name
- An individual can only belong to a single day creation class
- A human concept instance have a minimum of one name
- All creatures have a name instance attribute
- Creation created after and creation created before binary relations are transitive
- Both date and death date conceptual binary relations inherit all axiomatic constraints depicted in section 5.4.2

5.4.4.2 Use case example

The Creature and Creator formalism almost touches all core ontologies- manuscript, music and art- defined here. A typical example can be an author relation defined in Manuscript, art and music. A query like " ••• ••• •• •• ••• ••• •• •••• ••••" require a formalism that describe the being "••", services performed by the being and conceptual relationship with Manuscript.

5.4.5 Feast

Feasts are celebrated in commemoration of Jesus Christ, Our Lady Mary and the Saints [56 pp. 59-64]. Ethiopic church manuscripts and musical moods have strong ties with feasts as expressed in Lectionaries and Sanctorials of the church. Lectionaries and Sanctorials dictate what to read and play from manuscripts and music moods on a specific date. According to the [56 pp. 59-64], each day of the year is associated with feasts that commemorate either the saints, Jesus Christ, or our Lady Mary. Typical example is the relationship of manuscripts such as chant, miracle, biography, homily, ode with feasts. Chant manuscripts, inspired by St. Yared, attach music moods with days and seasons of the year while miracle, biography, homily and ode books relate praise, story and martyrdom for saints, angles, Our Lady Mary and Jesus Christ. Hence, we formalize a feast ontology for the reason of boosting expressive and inferencing power in the domain area.

5.4.5.1 Conceptualization

After putting forward the specification in Appendix A section 5, review of literatures and discussion with the domain experts, we have come up with the following glossary of terms , Table 5-6 and 5-7, for the initial conceptualization of the feast ontology.

Term	Type	Description
Feast	Concept	Describes feasts celebrated in the Ethiopic church. This spans classes of feasts commemorates Jesus Christ, Our Lady Mary and Saints feasts.
Jesus Christ Feast	Concept	Describes category of feasts celebrated in relation to Jesus Christ. Major and minor feasts are partitions for this class.
Our Lady Mary	Concept	Classes of feasts related to Virgin Mary. Feasts celebrated in relation to honor, life and miracle of virgin Mary are the main categories
Saints	Concept	Describes feasts commemorated for saints. Saints included angles, local saints, church fathers, ancient church martyrs, and , new and old testament Saints
Monthly feasts	Concept	Feasts celebrated monthly on a specific date
Yearly feasts	Concept	Feasts celebrated yearly on a specific date
Name	Attribute	Name of a feast
Feast type	Concept	Dictates the feast celebration date; the date the feast celebrated can be fixed, mobile or conditional on happening on events
Feast commemorate	Relation	Describes for whom a feast is commemorated
Precedence	Relation	Describes the order of precedence incase two feasts happen at the same date
Monthly celebrated on day	Relation	Monthly day numbers and feast association

Celebrated on date	Relation	Yearly dates in which a feast is celebrated
Celebrated on week	Relation	Describes week allocated for a feast

Table 5-7 Summary of glossary of terms for Feast conceptualization

Conceptual relation	Description
Type	Associate feast celebration date discriminator with a feast.
Writing entity for Feast	Associates a feast with writing entity.
Season for Feast	Associates a season with a feast
Music for Feast	Associate a music with a feast

Table 5-8 Summary of conceptual relationships for Feast conceptualization

Formalization axioms identified concepts and instance attributes are defined as follows

- A feast at least have a single day to be celebrated
- A feast at least have a creator or creature to commemorate
- All axioms defined in section 5.4.2 for date relations are holding true.
- Some feasts have precedence over other feasts if they happen at a specific date. This property is transitive
- All monthly feasts have a fixed date for at least the twelve months in the Ethiopic calendar with the exception of the 13th month, where the axiom holds true for the first 5 or 6 days.
- All feasts have at least one name
- All feasts belong to a fixed/conditional or movable feast type

5.4.5.2 Use case example

According to [56 p. 104], if "• • • • • •" falls on Sunday, a song "• • • • • • • • • • • • • • • •" from a chant book and verses Heb 11:32-40, Rev 6: 9-11, Act 19: 1-5, Psalms 9: 12-13 are read. Moreover, the day is commemorated for John Son of Thunder and is called "• • • • •"

5.4.6 Manuscripts

Manuscripts are an integral part in worship, service and moral education of the Ethiopic church. The Ethiopic church, as early education institution, act as a repository of the nation's manuscripts. A manuscript represents writings that are both in paper and parchment.

5.4.6.1 Conceptualization

According to experts in the domain and literature [53]-[57] various classification schemes for manuscripts are practiced in the church. We have witnessed classification based on a broad Spiritual/Secular categorization, content and context of manuscripts, division of local/translated and period of Ethiopian literature schemes. After a specification process (see Appendix A and B, section 6) a classification shceme, based on blocks of writing entities shown in Table 5-8 and 5-9, is devised to incorporate and glue together all classification schemes.

Term	Type	Description
Writing entity	Concept	Describes any writing entity. This can be viewed in classes of Book, Page, Chapter, Column, Paragraph and Verse.
Book	Concept	Classification of Ethiopic church books based on content. It comprises Administration and Counseling, Church Order, Compiled, Grammatical, Hagiography, Historical, Homily, Hymn, Instructional, Martyr, Mathematical, Miracle, Monks, Nature and Science, New and Old Testament, Ode, Philosophy, Prayer, Tradition and Culture, and Order classes of manuscripts.
Beginning writing style	Concept	Describes the declaration put in the first page of a manuscript. This can be in the name of Father, the Son and the Holy Ghost, the story of kings or flat with no declaration.
Bible	Concept	A class of manuscript which contain books of the

		New and Old Testament
Biblical manuscripts	Concept	Describe a class of manuscript that spans Church Order, New and Old Testament books
Calligraphy	Concept	Discriminator for the writing style employed in manuscripts. Right to left and left to right are the two widely used calligraphy styles.
Manuscript period	Concept	The four period of Ethiopic church literature.
Material (Paper, parchment)	Concept	Material on which manuscripts are encoded. Paper and parchment are the most widely used ones
Page layout style	Concept	Dictates the layout of a page in a manuscript, which can be single, double, triple or quadruple column.
Author	Attribute	Tells about the author/s of a manuscript
Chapter number	Attribute	Chapter number of a chapter
Creation date	Attribute	Describes the date a manuscript is finished being encoded.
Edition	Attribute	Edition of a writing entity
Height, Width	Attribute	Descries the dimension of a manuscript
Location	Attribute	Web location(URI) of a writing entity
Page number	Attribute	Page number for page class of writing entity
Physical location	Attribute	Tells where the manuscript reside
Publisher	Attribute	Publisher of the writing entity. This can be a monastery, church or an individual.
Allowable to be read in church	Attribute	Describes if a manuscript is allowed to be read outside church.
Title	Attribute	Title of the writing entity
Total page number	Attribute	Total number of pages of a writing entity
Translated from	Relation	Relates a manuscript to the langue it is translated from.

Verse number	Attribute	Verse number for a verse
Written in language	Attribute	Tells the language in which a writing entity is encoded
Category	Concept	Determinant in classifying writing entities based on content. Spiritual and Secular parameters are used.
Referenced in manuscript	Relation	Details references contained in a writing entity.
Read with feast, season, music, month	Relation	Associate a writing entity with months, seasons and music. This is an important feature of Ethiopic church manuscripts.
Order of book	Relation	Relates books for keeping sequences. It tells relationship between books by expressing the order in terms of successor and predecessor for collection.

Table 5-9 Summary of glossary of terms for Manuscript conceptualization

In liaison with identification of concepts, instance attributes and relations the research conceptualized additional conceptual relationships among concepts defined in manuscript classification scheme. Table 5-9 presents these conceptual relationships

Conceptual Relationship	Description
Beginning writing style	Associate a writing entity with writing style concept
Calligraphy	Relates a writing entity with calligraphy
Category	Models relationships between a writing entity and category determinant
Layout style	Map a writing entity with layout concept
Manuscript Period	Map a writing entity to a period of literate
Material made	Bind the information material the writing entity is made from
Contained in	Dictate the relationship between writing entities with other concepts.

Table 5-10 Summary of conceptual relationships for Manuscript conceptualization

Furthermore, the following axioms are identified

- A verse, chapter and page writing entities have exactly one verse, chapter and page numbers
- All writing entities have at least one calligraphy
- All writing entities at least have a material encoded
- A writing entities have at least a one page layout
- A book has exactly ones beginning writing style
- Hagiography manuscripts contain miracle, ode, martyr and homily manuscripts.
- Bible manuscripts contain exactly books from the New and Old Testament manuscripts
- Translated manuscripts contain books that are translated from other manuscripts
- Local manuscripts are books that are written in Ethiopia
- A writing entity can contain a collection of writing entities
- A writing entity might not have a title, edition, publisher and can have more than one title

5.4.6.2 Use case example

According to [56 pp.65-66] Ethiopic church commemorates saints by writing various manuscripts; spanning the martyrdom, homily, ode and biographies of saints. This enlighten a manuscript has a relationship with a creature. Also, manuscripts are classified based on contents [23 p. 45] such as manuscripts used for order of church, counseling, administration, chant and the likes. Moreover, Ethiopic church manuscripts have special relationship with other concepts as seen in use cases for feast, music, season and artwork.

5.4.7 Music

The Ethiopic church constitutes unique music composition and mood inspired by St. Yared. St. Yared devised the Ethiopic church music moods and defined a correlation scheme with seasons, verses of manuscripts and feasts. His five books, ”, “••”, “•• ••”, “••••”, “•••••”, “•••”, “••”, are the pillars of worship, season definition and music composition.

5.4.7.1 Conceptualization

Ethiopic church music is broadly classified by musical moods inspired by St. Yared. Ge'ez Izel and Araray are the three moods of Ethiopic church. A broader classification of Ethiopian music categorizes music based on music style, type and genre. Specification (see Appendix A, section 7) of lead to classification and identification of important terms defined in the Table 5.10 and 5-11.

Term	Type	Description
Genre	Concept	Describes Genre of Ethiopic church. This can be Adore, Ambasel, AnchiHoye, Araray, Geez ,Bati, Izle,MultiMode, Tizita, Gerers and Harmonic
Instrument	Concept	Classes of Instruments used in relation to Ethiopic music. It spans Chordophone, MemebroPhone, Idiophone and Wind classes of instruments
Music	Concept	Represent music of Ethiopic church.
Location	Attribute	Web location for a music resource
Physical location	Attribute	Physical location of a music resource
Publisher	Attribute	Distributor and encoder of the music resource
Title	Attribute	Name given for a music
Music category	Concept	Categorized a music based on content. This can be secular or spiritual.
Music type	Concept	Tells the category of a music based on the gist of the content. This can be music of politics ,recreation ,spiritual belief and work
Music style	Concept	Describes class of a music based on melody. This spans Ingurguro ,Mezemure ,Musho ,Zefen and Zema
Creation date	Attribute	Date on which the music is released
Lyric writer	Attribute	Tells who wrote the lyrics of a music

Melody composer	Attribute	Tells who compose the melody
Used reference	Attribute	References for a melody from other musical notes
Sing in season ,feast and with text	Relation	Tells association of a music with feast celebrated, happening of a season or manuscript declaration.

Table 5-11 Summary of glossary of terms for Music conceptualization

Conceptual relation	Description
Category	Associate music with category class. Category tells if music is spiritual or secular one.
Genre	Associate a music with Ethiopic genres
Instrument	Associate a music with of instrument used in it
Style	Associate a music with style class; Style categorize music based on melody
Type	Associate a music with type class; Type categorize music based on content
Contained In	Dictate the relationship between musical entities with other concepts.

Table 5-12 Summary of conceptual relationships for Music conceptualization

Formalization of axioms is entertained using these facts:

- A music genre has at least one music style.
- All music have at least have one music category, genre, type, melody, lyric and title.

5.4.8 Art

Art has a significant influence in worship, service, decoration of customs of church artifacts and honoring saints in Ethiopic church. According to the domain experts in Ethiopian Art, the Ethiopic church artwork represent traditional artwork trajectory of Ethiopia. Various classifications are used for categorizing Ethiopian artworks. However, to this day, no standard categorization system been put into practice. The Art ontology formalizes Ethiopian

church artwork in order to assess the relationship between music, manuscript and set aside concepts.

5.4.8.1 Conceptualization

Specification (see Appendix A and B, section 8) of art ontology paves a way for identification of concepts, instance attributes and relations in Ethiopic church paintings. We have learned that there is no clear-cut agreement by the domain experts on the classification scheme of Ethiopic church paintings. However, a classification scheme based on settings and content of paintings suffices to reconcile the various views by the domain experts. In relation to this, manuscript illumination, panel paintings and wall paints are identified as major partition of Ethiopic church paintings. Table 5-113 and 5-13 details terms and relationships of the conceptualization

Term	Type	Description
Art	Concept	Describe artworks in the context of church. Here, artwork spans paints of the church
Arch of Noah	Concept	A category of painting describing the Arch of Noah, usually found in the window of a church.
Beast	Concept	A category of painting depicting a monster that eats people.
Equestrian saints	Concept	A category of painting that shows about saints that are portrayed usually with a horse
Non Equestrian Saints	Concept	A category of painting that details saints whom are not equestrian
Local saints	Concept	A category of painting that depict local saints, can be priest, martyrs, or any local church person treated as a saint
Exodus	Concept	A category of painting where Moses led the Israelites out of Egypt portrayed.
Jacob dream	Concept	A category of painting about Jacobs dream

		where angles are moving up and down with a ladder stretched from heaven to earth
Judgment day	Concept	A category of painting, which shows scenes of judgment day.
The Devil	Concept	A category of painting that portray the Devil
Trinity	Concept	A category of painting that depict the holy trinity
Mariology	Concept	A category of painting that depicts the life of Our Lady Mary. It spans paintings related with Annunciation, Ascension, Assumption, Beta, Birth of virgin Mary, covenant of Mary, Formation, Dream of Anna and Yakima, Flight to Egypt and Miracles of Virgin Mary.
Christology	Concept	A category of painting that depicts the life of Jesus Christ. It comprises paintings of Baptism, Deposition, Crucifixion, Circumcision, Descent from the cross, Entry to Jerusalem, Flagellation, lamentation, Last supper, Resurrection, Miracles of Jesus Christ, Nativity, Temptation and The first teaching
Category	Concept	Describes the category of a painting based on the content put in a painting. This can be painting related to Christ and Virgin Mary life, Trinity, the Devil, Judgment day, Jacob dream, Exodus, Local saints, Equestrian and non Equestrian Saints, Beast and Arch of Noah.
Church	Concept	Represent a concept of church architecture. Church architecture can be concentric or otherwise. The architecture dictates the placement of paintings in a church wall
Panel painting	Concept	Describes a class of artwork painted on a panel. Panels can have single, double, tri or pendant

		dimensions.
Drapery	Concept	Tells the way clothing is drawn which in turn tells about the era of the style. Floral decoration, parallel fold, single colored are values for Drapery style.
Manuscript illumination	Concept	Describe a class of artwork that have special characteristics of being painted on a manuscript
Model of Face	Concept	Describes the way the face of people is drawn. This can have values of long and with shade styles
Period	Concept	Describes the Ethiopian church artwork period. This can be first and second Gonderian, Medieval and Transitional. There is no clear-cut agreement on period of artwork, due to such debate the classification can be amended in the future.
Register	Concept	Logical partition of a wall in a church. There are three logical partition of a church namely: lower, middle and upper. Additionally, each of the partitions is further dissected with left and right notion.
Wall direction	Concept	Tells direction of a wall in a church. This can be North, South, East, West for circular churches
Wall painting	Concept	Describes a class of artworks that are portrayed on a wall of a church
Caption	Attribute	Describe the caption used for an artwork.
Creation Date	Attribute	Describe date of creation/ the date the painting is drawn
Height, Width	Attribute	Describe the dimension of an artwork
Location	Attribute	Web location of an artwork

Physical location	Attribute	Describes the place where the artwork is currently reside
Material	Concept	Describes material used in an artwork. This can be paper, cotton on Gesso, wood, skin or tempera on Gesso
Door and window on a wall	Relation	Tells whether a wall in a church has a door and window.

Table 5-14 Summary of glossary of terms for Art conceptualization

Conceptual Relationship	Description
Category	A relation defined to associate an Artwork with a category of a concept
Drapery	Associate an art with the drapery style
Material	Relate an art with the material it is made form
Model of Face	Related an artwork with the model of the face
Contained in	Dictate the relationship between an artwork with other concepts. Inside the artwork domain, this can be in logical partition and wall in a church. It can also relate with concepts outside the artwork domain. For instance, an artwork can be contained in a manuscript.

Table 5-15 Summary of conceptual relationships for Art conceptualization

The following axioms are used to formalize artworks:

- All artworks belong to at least a single category of painting
- An artwork exhibit a minimum of single drapery style and model of face
- An artwork at least is portrayed in a single material
- Category of paintings can supplement each other; can coexist together in a one painting
- Manuscript illumination paintings are paints that are contained in a manuscript.
- For a wall painting to exist, there should be church on which the painting reside on certain specific direction
- An artwork can have more than one caption

5.4.8.2 Use case example

An artwork in a church has a specific placement on direction of wall in Ethiopic church [57 p. 273]. For instance, the following paintings are portrayed on each wall of a church

- On the East side, miracles of Christ and martyrdom of apostles
- On the West side, life happening of Christ and equestrian saints
- On the North side, martyrdom of saints and Our Lady Virgin Mary
- On the South side, life happenings of Virgin Mary

This example shows the classes of paintings based on church wall direction.

CHAPTER SIX

6. Implementation

6.1 Overview

Proof of concept for the proposed model and abstracted ontologies is magnified by the development of a prototype system. We have used the state of the art in semantic web frameworks, ontology workbench and intuitive humans to computer interface design principles. In developing the prototype we have practiced a phased iterative approach. Formalization and implementation of the ontology conceptualized and development of a semantic search engine for the proposed model are the two salient phases employed. The first phase is marked by close participation of the domain experts for pruning of ontology formalisms and use of an integrated ontology development platform. Conceptualized ontologies are formalized using OWL-DL formalism vis-à-vis acquisition of sample instance data for consistency and inference checking in this phase. The second phase mainly concentrates on realization of the model proposed in Chapter 4. It spans design of form-based interface, selection and customization of third party keyword-based search engine, partial digitization of documents into RDF and webpage, and implementation of semantic search engine for a single web domain. Formalized ontologies and semantic plus keyword-based search engines are the end product of the implementation process.

The prototype is developed bearing in mind that it is used for augmenting later experimental process as well as for iterative maintenance of ontologies designed for the domain of interest. The aim of this chapter is therefore, to put forward implementation details used for the research.

6.2 Tools Utilized

At each phase of the development, we have selected and make use of tools. This section presents tools utilized in the course of developing the prototype.

1. ***TopBraid Composer***

TopBraid Composer is a tool used for specification, formalization and implementation of an ontologies. TopBraid is largely used in the first phase of implementation and formalism of ontology due to its support for W3C standards, selected ontology development process and configuration and change management features. Furthermore, the composer is a preferred choice of ontology development workbench as it offers added benefits for post development process such as full integration in inferencing, assertion and SPARQL support.

2. ***Apache Nutch***

Apache Nutch is a Java based open keyword-based search engine. It employs Apache Lucene for the search and index components and Apache Tomcat for handling HTTP requests. We have used Apache Nutch to crawl, index and rank digitized web pages contained in a single web domain for the domain of area. Furthermore, Nutch is used as a keyword-based search engine component implementation for the model proposed. Query results from Nutch are customized with rating display features so that users can describe their degree of satisfaction.

3. ***Apache Lucene with ARQ support (LARQ)***

LARQ arms Jena's SPARQL query engine with Lucene searching capabilities. We have used LARQ in order to match conceptual graphs in semantic searches with partial information searching capability employed by Lucene. Moreover, the main reason behind using LARQ lies in avoiding bias and its sound integration with Jena. Since we are using a Lucene based keyword-based search engine it is ideal to use Lucene with the RDF based query engine to effectively eliminate variations that arose with language specific issues

4. ***Jena Framework***

Jena is used for SPARQL manipulation, reasoning support needed and its support for LARQ. Jena provide models for interacting with defined ontologies and RDF store for chaffing relevant results based on assertions and inferencing. Jena is selected for this purpose as it is the preferred standard for semantic web.

5. ***JavaScript***

JavaScript a client-side web programming language used for embedding scripts that run on the address space of a client machine. We have used JavaScript to implement Amharic Query Interface. The reason why we prefer to use JavaScript opposed to other client side solution is, its being lightweight and support across various web browsers.

6. ***MySql Database Engine***

MySql database is an open source database management system. The research makes use of MySql database for storage of user response in relation to query results returned.

7. ***Tomcat 5.0.7***

A Java based web container used for the purpose of handling HTTP requests and relaying responses from other peer components in the model proposed. We have chosen Tomcat as it is a free and open source product and is Java enabled.

In addition to the tools described in this section, we have used Java programming language for implementing the various components of the proposed model.

6.3 Demonstration

Discussions of the implemented prototype system for both of phases are presented in this section. Implementation of all the features of the model proposed, except limitations of a query interface for humans, are demonstrated in this section. The limitation is due to scope demarcation of the research and inexistence of preferred technology at disposal.

In the first phase of implementation, the eight ontologies described in chapter 4 are implemented in the following fashion.

- Representation of conceptualization to OWL DL formalisms. This includes conversion of concepts to classes, instance attributes to properties, sub concepts to subclasses and axiom integration.
- Instance data feeding for consistency checking and inferencing

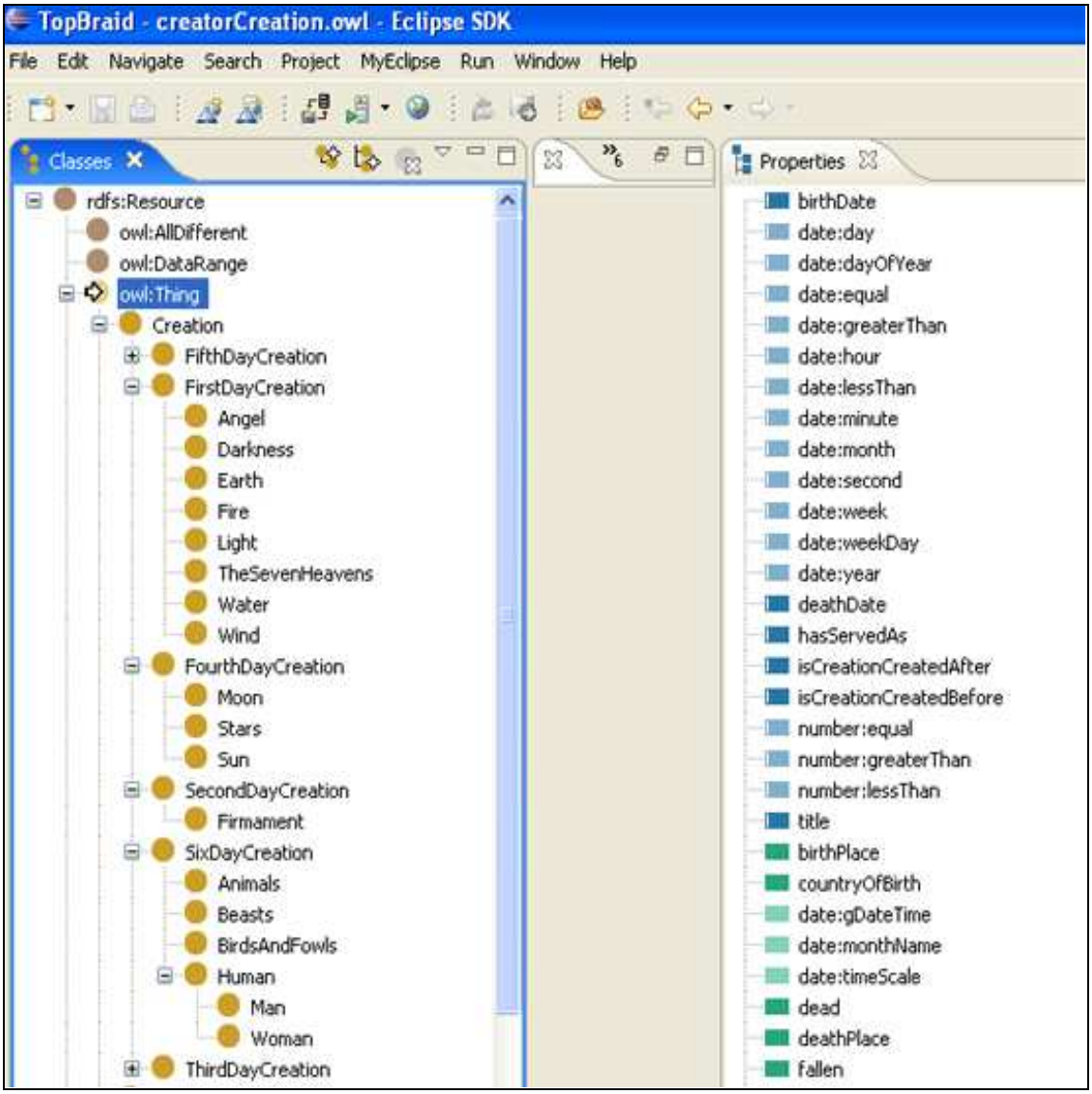

Figure 6-1 A glimpse of ontology development using TopBraid ontology workbench

The second phase of the implementation encompasses customization Nutch keyword-based search engine and the implementation of a form-based semantic search engine. Customization of Nutch Keyword has the following subtasks

- Localization of interface terms to support Ethiopic
- Arming search result sets with ranking features for “Most relevant”, “Relevant”, “Less Relevant”, “Irrelevant” options.

Figure 6-2 A glimpse of search query result by Nutch keyword-based search engine

The implementation of semantic search engine employs three phases namely: interface design, query formulation and result presentation phases. Interface design phase involves design of a form-based search interface where the user is presented with concepts and list of instance attributes. The interface allows user to select a concept and accompanying attributes for provision of query parameters. The interface shows concepts based on their hierarchical relationships so as to avoid ambiguities. Query formulation commences right after the user formulate a query and dispatch a request. We have implemented modules that take the query from the user and construct SPARQL query on the fly using notions of left to right operator precedence rules. In formulating queries, data items that are represented in Ethiopic date and numeral are changed to corresponding Gregorian date and number format to facilitate comparison operations. Moreover, insertion of Lucene specific search routines is addressed

at this stage. The last phase involves computation and manipulation of SPARQL query using LARQ engine embedded in Jena semantic framework and present query results for the user to rate relevancy. Here, SPARQL queries are wedded with ontologies designed and RDF store for inferencing and retrieval of relevant query results. Query results then are formatted and presented for the user in categories of concepts and list of URIs.

CHAPTER SEVEN

7. Experiment

An experiment is conducted to assess the validity of the ontologies designed along with a comparison of query results by a keyword-based search engine with that of a semantic based search in order to unveil deficiencies in the ontology models is the main focus of this chapter. Discussion of the methods used, activities followed and results obtained in the course of conducting an experiment is also presented in detail.

7.1 Data selection and Acquisition

One of the activities outlined in the methodology employed for ontology formalism is data selection and acquisition. Data selection involves specification, digitization and formalization of datasets required for evaluation of the proof of concept and ontology formalism proposed in this experiment. Data selection is a governed selection of datasets that are related to conceptual description on the ontology designed. This is mainly due to the fact that concepts usually represent a mapping of the real entities or the heart of the domain problem. The following are the steps followed and parameters used in the data selection process:

Step 1: Specification

Specification of datasets for the experiment is closely related with specification for ontology formalism. The main parameter for selecting representative datasets is the conceptual relationships in ontologies. We along with the domain experts have weighed the important concepts modeled in the ontologies and moved along to the digitization task. The decision on selecting representative datasets is also influenced by the volume of data to be digitized, the availability of the data at hand and encoding ease. For instance, we are unable to digitize the book of "• •" due to difficulties in the encoding scheme used in the book and from its large volume

Step 2: Digitization

After selecting representative sample documents and data for each of the concepts, the digitization process commences. The digitization process is handled in two veins. Collecting datasets from organizations and performing secretarial tasks. We are able to encode 68 out of 80 books of the Bible, a single miracle book, a single biography book, 4 ode books, 3 prayer books, and almost all feasts data collection, a handful of artwork descriptions and very minimal musical data. Furthermore, instance data that are associated with creature and creature ontology, date and season are also digitized

Step 3: Formalization

Converting the digitized data to RDF and webpage format is the last step in data selection and acquisition process. Digitized data is annotated with ontology specification with the help of domain experts, literatures and observation. The end product of this process is RDF data sets. Furthermore, alignment of the digitized data by converting it to WebPages with master and slave link structure is devised. For instance for the bible books we have maintained a structure that have links for each of the books contained in the bible along with chapter links for each of the books. This approach is followed to facilitate searching and crawling in keyword-based search engines.

7.2 Procedures for query formulation

In evaluating the validity of ontologies formalized, we have used two groups of domain experts. In the first group, we assign experts who aided in formalization of the ontologies abstracted while the second group is composed of new individuals who only have the knowledge of the domain area. We have selected individuals in each group based on merit of knowledge in the domain area and willingness to participate in the experiment. Each group is assigned with an individual that make up a total of two individuals for assessing relevance of query results returned by keyword-based search engine their semantic search counterparts. The number of experts in each group is decided to be two for a mere reason that semantic

search are domain dependant and it only requires knowledge in the domain area. The following procedures are followed in evaluating query results:

- Definition of queries by domain experts after brainstorming tasks on the purpose of the research is performed.
- Evaluation and rating of query results returned by keyword-based search engines as well as semantic based search engines.
- Comparison of query results by selecting the top 20 results returned by both engines using precision and relevancy parameters.

7.3 Experiment setup

In order to perform the experiment, selected domain experts are asked to formulate a query based on the concept "•••••". We have taken this concept on consensus with the domain expert as it participates in all concepts defined in the domain area. Each individual is given a chance to formulate three queries pertaining to the concept "•••••". The following are the harvested query from each individual:

Individual 1

Query 1• •••••
Query 2• ••••••• ••••• ••••
Query 3• ••• ••••• ••••••• •••••• •• ••••••• ••

Individual 2

Query 1• ••••• •••• ••?
Query 2• ••••• ••••••• ••
Query 3• ••••• ••••• ••?

Furthermore, for the purposes of data analysis nominal values are defined in order to facilitate the relevancy of query results:

Description	Value
Most relevant	1
Relevant	.75
Less Relevant	.25
Irrelevant	0.0

Table 7-1 Nominal values for query evaluation

Finally, gathered queries are inputted to both keyword and semantic search engine by the researchers for a mere reason of incompetence of domain experts with computers.

7.4 Evaluation Result and Discussion

According to [71], for evaluating the performance of information retrieval systems coverage, time lag, presentation, user effort, recall and precision are used. We have taken precision with weighted relevancy scale defined in Table 8-1. The chief reason for choosing precision and rejecting the others performance measures lie in the objectives of the research; to only validates designed ontologies. Moreover, we have considered the top 5 results returned by both search engines to avoid bias raised by limitation of annotation of pages using RDF. The following results are acquired for each query:

Query	Engine	Most relevant	Relevant	Less Relevant	Irrelevant	Total/5	Precision Score
·····	KBSE	5	-	-	-	5	100%
	SSE	2	1	2	-	3.75	75%
····· ····· ····	KBSE	1	-	-	4	1	20%
	SSE	1	-	2	2	2.0	40%
··· ····· ····· ····· ·· ····· ··	KBSE	-	-	1	4	.5	10%
	SSE	1	1	1	2	2.25	45%

····· ···· ··?	KBSE	-	2	-	3	1	20%
	SSE	1	1	1	2	2.25	45%
····· ····· ··	KBSE	-	-	1	4	.5	20%
	SSE	1	1	-	3	1.75	35%
····· ····· ··?	KBSE	1	1	-	3	1.75	35%
	SSE	1	-	-	3	1.00	20%

Table 7-2 Data analysis result for top 5 query results

Note KBSE, SSE stands for Keyword-Based search engine and Semantic Search engine respectively.

Considering the precision score, the semantic search engine returns a more precise query result than that of keyword-based search engines. For all queries harvested, on average the semantic search engine performs (205 of 600) 43% in contrast to 34% (260 of 600) to keyword-based search engines showing a 9% advantage for semantic search engine. Moreover, keyword-based search genies take 60% (18 of 32) of irrelevant results in comparison to semantic search engine return 40% (12 of 32) irrelevant results. Also, a tie (7 of 14) for most relevant result is reflected on both search engines.

Seeing the figures, the semantic search engine performs well overall with an equal precision result mainly due high figure in the first query. Narrowing the relevant query from to the top 2 results shows a significant result change as shown in Table 8-3 with 5 to 2 shows results in a more precise for semantic search engines than that of keyword-based counter parts. Keyword based search engine have 43% (262 of 600) precision compared to 79% (475 of 600) precision by semantic based search engine. Semantic search engine return 64% (7 out 11) for ‘most relevant’ measure in contrast to 36% (4 out of 11) for keyword-based search engines that shows the former engine is more precise.

Query	Engine	Most relevant	Relevant	Less Relevant	Irrelevant	Total/2	Precision Score
·····	KBSE	2	-	-	-	2	100%
	SSE	2	-	-	-	2	100%
····· ·····	KBSE	1	-	-	1	1	50%
	SSE	1	-	1	-	1.25	62.75%
··· ····· ····· ····· ·· ····· ··	KBSE	-	-	1	1	.5	25%
	SSE	1	1	-	-	1.75	87.5%
····· ····· ··?	KBSE	-	1	-	1	.75	37.5%
	SSE	1	1	-	-	1.75	87.5%
····· ····· ··	KBSE	-	-	-	2	0.0	0%
	SSE	1	1	-	-	1.75	87.5%
····· ····· ··?	KBSE	1	-	-	1	1.00	50%
	SSE	1	-	-	1	1.00	50%

Table 7-3 Data analysis result for top 2 query results

Note KBSE, SSE stands for Keyword-Based search engine and Semantic Search engine respectively.

The experiment shows that ontologies formalized greatly help the searching process with precision rate close to 80%. However, for free query like query 1 a significant decrease in precook resulted for large set of query results. This shows that more data items need to be annotated with the ontology abstracted in order to have better quality search results.

CHAPTER EIGHT

8. Conclusions and future work

8.1 Conclusion

Thirst in knowing, learning and assimilating information is a flame burning inside every creature. Human beings, as an intelligent creature than others, quench this need by devising a way for information exchange and retrieval within and across themselves. Oral narratives, inscriptions and symbolic representations were largely exercised in the past in such respects. However, limitations on reaching large demography, haphazard representation of information and most all of unavailability of information at needed time impede the popularity of the aforementioned schemes. The invention of computers and boom of formal mathematical logics paves a way for the birth of knowledge representation schemes that have unprecedented advantage over their previous counterparts. Moreover, the rise of disciplines like Artificial Intelligence and Cognitive science augment the knowledge representation and exchange endeavor by unveiling new representation schemes imitated from human thinking process.

The World Wide Web sits at the pinnacle of the information retrieval, extraction and exchange process in computers. Search engines chaff relevant information for the irrelevant ones and present human consumable information at WWW. However, disparity in query results returned by the current search engines chiefly due to cultural and domain of interest variations as well as dependency on information representation scheme targeted for human consumption sees inception of a new platform-Semantic web. Semantic web makes use of conceptual hierarchies, their relationship and logic rule to cater the deficiencies exhibited in the current web.

Ontologies and logic are used in the semantic web for representing knowledge and conveying sound query result for a domain of interest. Ontologies allow sharing and conceptualizing of a domain of interest using explicit formalisms while logic arms the semantic web with machine inference capability. A number of studies show that variations in culture and

domain of interest hamper the quality of query results in the semantic web. Also, it has been pointed out that formalization of the knowledge contained in domain of interests and cultural spectrums is one of the lofty challenges in semantic web. Thus, the impetus of the research arises from observing such formidable challenges and a zest on whether top-level Ethiopic concepts are property represented in the new platform. To this end, we have selected Ethiopic church manuscript, music and art domain area as it envelopes the two challenging facets of the semantic web at once; culture and domain of interest variations.

Ontologies that capture the extremities of the knowledge contained in the domain area are abstracted after consulting related studies and performing activities stated in selected ontology development methodology. Competency questions, church literatures, formal and informal discussions are mainly entertained in the development process. Eight key ontologies are churned out as a result of the above exercise. Number and Date Time ontologies, mainly due to the incompetence of XML Schema, formalize numeral representations and date and time modalities found in Ethiopic language and church calendar respectively. Time ontology that models temporal concepts such as seasons of music and time divisions for worship and their relationship with concepts defined in date/time ontology. Creature and Creator ontology for conceptualizing creatures according to the order of creation defined in church and Creator conceptual hierarchies and relationships. Feast ontology for modeling feasts celebrated in commemoration to various concepts in creature and Creator ontology and relationships defined with date, manuscript, time and musical concepts. Manuscript ontology for abstracting classes of concepts elaborated in taxonomy of church books and relationships defined within and across music, feast, date, art, and music concepts. Music ontology that entertains the modeling of Ethiopic church music modes and relationship defined to manuscript and season major concepts. Lastly, art ontology for formalizing paintings found in church walls, manuscript illumination and wooden carvings and their relationship with manuscripts.

Furthermore, development and implementation of a model for retrieval and storage of information basing the abstracted ontologies is entertained. Acquisition, digitization and conversion sample representative dataset to RDF and WebPages is also performed. Finally,

an experiment is conducted by considering two searching platforms, keyword-based and semantic. The experiment is conducted after acquiring reasoning queries defined by domain experts without subjecting them to computers and later asked the relevance of query results returned by the above platforms. Initial results show ontology based searching has above par quality query results with that of keyword-based search engines and most of all approve the validity of the ontologies to an acceptable degree.

8.2 Future work

In the course of conducting the research, we have identified some open issues to be addressed in the future. Fundamentally, these issues are categorized into three main streams; issues related to enhancing and extending the abstracted ontologies, improving the model proposed and augmenting set aside issues related to standards of semantic web. Formalizing ontology to capture the unbounded knowledge manifested and internalized in Ethiopic church and culture is not a one time study. The research identified the most demanding concepts in the domain area due to time and scope limitation. Thus, enhancing and extending the already defined concepts, properties and axioms is a work that calls for attention in the future. Moreover, the following concepts are left unaddressed in connection to ontology abstraction:

- Devising ontology for church architecture which can be used in relation to architectural, engineering and artwork studies. Ethiopic church is known for its unique design and architecture in church design that has significant relationship with artworks. For instance, querying "•••• ••• •••• ••• •••• ••" requires identification of the church and the specific walls, some of the walls are only being allowed for high priests. Such queries highly depend on the architecture of the church as there are patterns exhibited in various church structures.
- Full-blown art ontology that cover sculptures, monuments and various wooden carvings. The research only considers paintings that have a lion share of the artwork in Ethiopic church. However, the ontology would be more complete if the aforementioned art areas are included.

- Ontology for formalizing levels of educational institutions practiced by church. This helps in unveiling new relationships embedded with manuscript and music as well as to some degree artworks.
- Incorporating and extending the developed ontology with other related cultural values that are not included in the domain area in order to acquire a global view of Ethiopian culture

The second issue that needs further study is the model we proposed in the research. We have developed a model for retrieval of information in a single web domain and limited set of digital documents. Also, we refrained from using an open ended natural language query interface and chose to stick to a form-based query interface mainly for evaluation of the formalized ontologies. These two very facts call for further improvements in the model. The following are left aside tasks that need further scrutiny

- Designing a full-scale semantic search engine which include crawling, indexing, ranking and storing a semantically annotated Ethiopic church manuscript, art and music pages on the web
- Designing an open-ended natural language query interface and associated processing schemes for matching conceptual islands. This includes natural language processing mechanisms exhibited in traditional keyword-based search engines as well as traversing conceptual graphs in the knowledge abstraction.
- Creating and incorporating components for annotation and maintaining knowledge contained in the domain area. These components will enable annotation of new knowledge, ontology learning and provision of a new platform among domain experts.
- Defining ontologies that address semantic relationship between Ethiopic language words for better matching of concepts defined in the ontology. For instance, querying "•••• ••••" might require matching conceptual descriptions like "••• ••••", "•••• ••••".
- Digitization and acquisition of documents in large bases to capture and model further relationships of Ethiopian culture. A collaboration project with various institutions

both abroad and at home for preservation of knowledge should also be considered in this respect.

Finally, the research put in perspective, identification of issues surrounding standardization and localization of Ethiopic specific concepts within semantic web. The following are a list of identified issues

- Support for Ethiopic specific localized data types in XML Schema especially for numerals and date/time. Currently XML Schema ignores localized data types and unless such issues are handled properly representing Ethiopic based concepts will be incomplete and haphazard.
- Extending and creating abstractions for SPARQL query language to handle Ethiopic specific localized data types. SPARQL uses built-in routines that work primarily on the data types defined in XML Schema. Extending the capabilities of SPARQL to perform additional computations require further study in the area. For example comparing date values "፲፱ ፻፱ 1999" and "፲፱ ፻፱ 1999" require comparing algorithms embedded in the query language.
- Localization of SPARQL query language so as to facilitate easy querying and exploring of concepts defined in Ethiopic.

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Appendix A -Ontology specification

1. Number Ontology Specification

Purpose

- to model Ethiopic numerals within the context of XML Schema
- to make a room for annotation of Ethiopic Numerals embedded in manuscripts, musical notations and artworks

Scope

- Conceptualization only deals with mapping of Ethiopic numerals with that of Arabic numerals. The path on how to perform arithmetic and relational manipulations are differed
- The conceptualization process is limited only to XML Schema type for non negative integers

Sources used

- WC3 XML Schema specification
- Fr. Emmanuel Fritsch. The Liturgical Year of the Ethiopian Church, 2001
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Sample competency questions

1. What is the corresponding between Ethiopic and Arabic numerals?
2. What are ranges of numerals in Ethiopic that are not supported in XML Schema?
3. Is it possible to extend XML Schema and make use of existing Arabic numerals?
4. How are numerals in languages like Hebrew, Greek and Roman handled in XML Schema?
5. What is the significance of usage of Ethiopic Numerals in Ethiopic church?

2. Date Ontology Specification

Purpose

-to model Ethiopic calendar within the context of XML Schema

Scope

- Only high-level formalization of the date/time representation of Ethiopic calendar
- Manipulation of date/time calendar is not an issue. For instance comparison of values of dates

Sources used

- WC3 XML Schema specification
- Fr. Emmanuel Fritsch. The Liturgical Year of the Ethiopian Church, 2001
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Sample competency questions

1. What are the basic facets of Ethiopic date/time?
2. Is it possible to extend XML schema date time data type for Ethiopic calendar?
3. What kind of pattern exhibited in Ethiopic date/time format?
4. What are the restrictions imposed on day, month and year formats?
5. What kind of correspondence exists between Ethiopic calendar and that of Gregorian calendar?
6. Can Gregorian date schema be sufficient for representing date/time datasets in Ethiopic church domain?

3. Time Ontology Specification

Purpose

- to model temporal concepts in Ethiopic church manuscript, art and music domain of interest

Scope

- no limitation on temporal times however the temporal concept should be expressed using interval and instances

Sources used

- WC3 Time ontology
- Fr. Emmanuel Fritsch. The Liturgical Year of the Ethiopian Church, 2001
- ·· ····· ··· ···· ·········· ····· ···· ····· ····· ···· ··· ··· ··· ···· ····· ····· ····· ··· · ··· ··· ····· ···
- His grace Abune Mekarios. Ethiopian orthodox culture book H. PETER ALESSO and CRAIG F. SMITH, The Ethiopian Orthodox Tewahedo Church Faith, Order of Worship and Ecumenical Relations, 1996

Sample Competency questions

1. What are the entities that are defined in terms of duration and date/time interval?
2. How can the time ontology, defined mainly in Gregorian format, be extended to Ethiopic date/time format?
3. What are the facets related with W3C time ontology that need to be defined in Ethiopic temporal time context?

4. Feast Ontology Specification

Purpose

- to model feasts celebrated in Ethiopic church and their relation with other concepts

Scope

- Only Ethiopic church feasts are considered, Ethiopian public feasts that are not related to church domain are ignored

Sources used

- Fr. Emmanuel Fritsch. The Liturgical Year of the Ethiopian Church, 2001
- ·· ····· ··· ···· ·········· ····· ···· ····· ····· ···· ·· ·· ·· ···· ····· ····· ····· ·· · ·· ·· ····· ···
- His grace Abune Mekarios. Ethiopian orthodox culture book H. PETER ALESSO and CRAIG F. SMITH, The Ethiopian Orthodox Tewahedo Church Faith, Order of Worship and Ecumenical Relations, 1996
- Dr. Thomas from Ethiopian Language Studies
- Ato Sergewe from Ethiopian Language Studies
- Ato Serse dengel fresenbet from Yared Music School

Sample competency questions

1. What is classification scheme is used to classify feasts?
2. What is the relationship of feasts with manuscripts, music and artworks?
3. For whom a feast is commemorated?
4. What is the relationship with side concepts like time, date and creature and creator?

5. Creator creature Ontology Specification

Purpose

- to model classification of creation in Ethiopic church and relationship with other related concepts

Scope

- Classification scheme considered is solely based on Ethiopic church notion. It doesn't extend and debate biological counterparts

Sources used

- ·· ····· ··· ···· ·········· ····· ···· ····· ····· ···· ··· ··· ··· ···· ····· ····· ····· ··· · ··· ··· ····· ···
- His grace Abune Mekarios. Ethiopian orthodox culture book H. PETER ALESSO and CRAIG F. SMITH, The Ethiopian Orthodox Tewahedo Church Faith, Order of Worship and Ecumenical Relations, 1996
- Ethiopian Orhodox Bible

Sample competency questions

1. What is classification scheme is used to classify feasts?
2. What is the relationship of creature/creator with manuscripts, music and artworks?
3. What are the commonalties in creature/creature concept?

6. Manuscript Ontology Specification

Purpose

- To model manuscript classification and conceptual relationships defined within the Ethiopic church domain.

Scope

- manuscripts only span both published and unpublished ones

Sources used

- BiblTex ontology sepecifcaion
- W3C bible ontology
- Dublin core
- Dewey Classification Scheme
- National Archive and Library of Ethiopia (NALE)
- Fr. Emmanuel Fritsch. The Liturgical Year of the Ethiopian Church, 2001
- ·· ····· ··· ···· ·········· ····· ···· ····· ····· ···· ··· ··· ··· ···· ····· ····· ····· ··· · ··· ··· ····· ···
- His grace Abune Mekarios. Ethiopian orthodox culture book H. PETER ALESSO and CRAIG F. SMITH, The Ethiopian Orthodox Tewahedo Church Faith, Order of Worship and Ecumenical Relations, 1996
- Dr. Thomas from Ethiopian Language Studies
- Ato Sergewe from Ethiopian Language Studies
- Ato Serse dengel fresenbet from Yared Music School
- Dr. Anna Wiese from University of Humburg
- Ato Mersha Alehenge from University of Humburg

Sample competency questions

1. What is classification scheme is used to classify manuscripts?
2. Parameters used in classification of manuscripts?
3. Definition of basic domain terms reacted with manuscripts?
4. What is the relationship of manuscripts with music and artworks?
5. What is the relationship with side concepts like feasts, time, date and creature and creator?
6. What kind of catalogue used in major libraries and what is the drawback of the schemes employed?
7. What are the features used to express manuscripts in church and libraries?
8. How are manuscripts related with each other?

7. Music Ontology Specification

Purpose

- To model manuscript classification and conceptual relationships defined within the Ethiopic church domain.

Scope

- Only musical works that are of the Ethiopic church is considered.

Sources used

- Music brainz specificaiotn
- Serse Dengle Feresenet,"School of Zema Bet", Term paper on Ethiopian music notation
- Zenebe Bekele,A Preview of Ethiopian Music
- Fr. Emmanuel Fritsch. The Liturgical Year of the Ethiopian Church, 2001
- Kessis KefYalew Mehari. The Most Versatile Ethiopian Scholar, St. Yared and His Outstanding Works, 2004
- Ato Serse dengel fresenbet from Yared Music School

Sample competency questions

1. What is classification scheme is used to classify music of Ethiopic church?
2. Definition of basic domain terms reacted with music modes of Ethiopic church?
3. What is the relationship between chant books and music of Ethiopic church?
4. What is the relationship between musical modes and seasons as well as feasts?
5. What are the additional facets used or classify Ethiopic church music's?

8. Art Ontology Specification

Purpose

- To abstract the classification of Ethiopic paints
- To model logical relationships within and across other domains.

Scope

- Only paintings in Ethiopic church is considered
- Identification of terms is only confide in the area of Ethiopic church and not in modern contemporary artworks

Sources used

- Marilyn Heldman, Stuart C. Munro-Hay and Roderick Grierson, African Zion: The Sacred Art of Ethiopia, New Haven ; London : Yale University Press, 1993
- ·· ····· ··· ···· ·········· ····· ···· ····· ····· ···· ··· ··· ··· ···· ····· ····· ····· ··· · ··· ··· ····· ···
- His grace Abune Mekarios. Ethiopian orthodox culture book H. PETER ALESSO and CRAIG F. SMITH, The Ethiopian Orthodox Tewahedo Church Faith, Order of Worship and Ecumenical Relations, 1996
- Ato Abebawe Ayele from Ethiopian Art School
- Art and Architecture Thesaurus online library

Sample competency questions

1. Method of cataloguing Ethiopian artworks?
2. Classification parameters for Ethiopic church artworks?
3. What special relationships exist with Ethiopic church manuscript and music?

Appendix B -Cell model for ontology formalized

1. Number Ontology

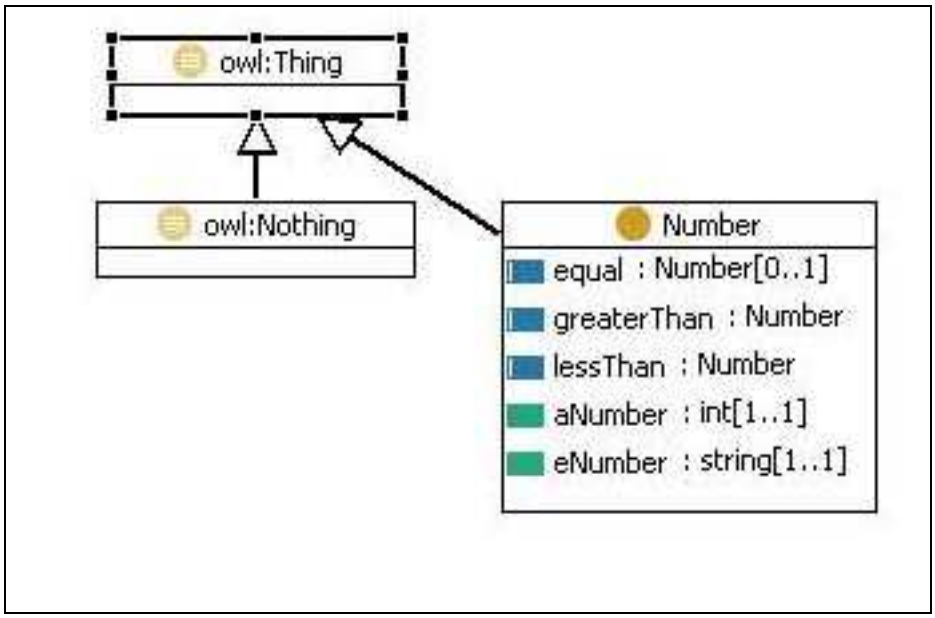

Figure 1. Sample cell model for Number ontology

2 Date/Time Ontology

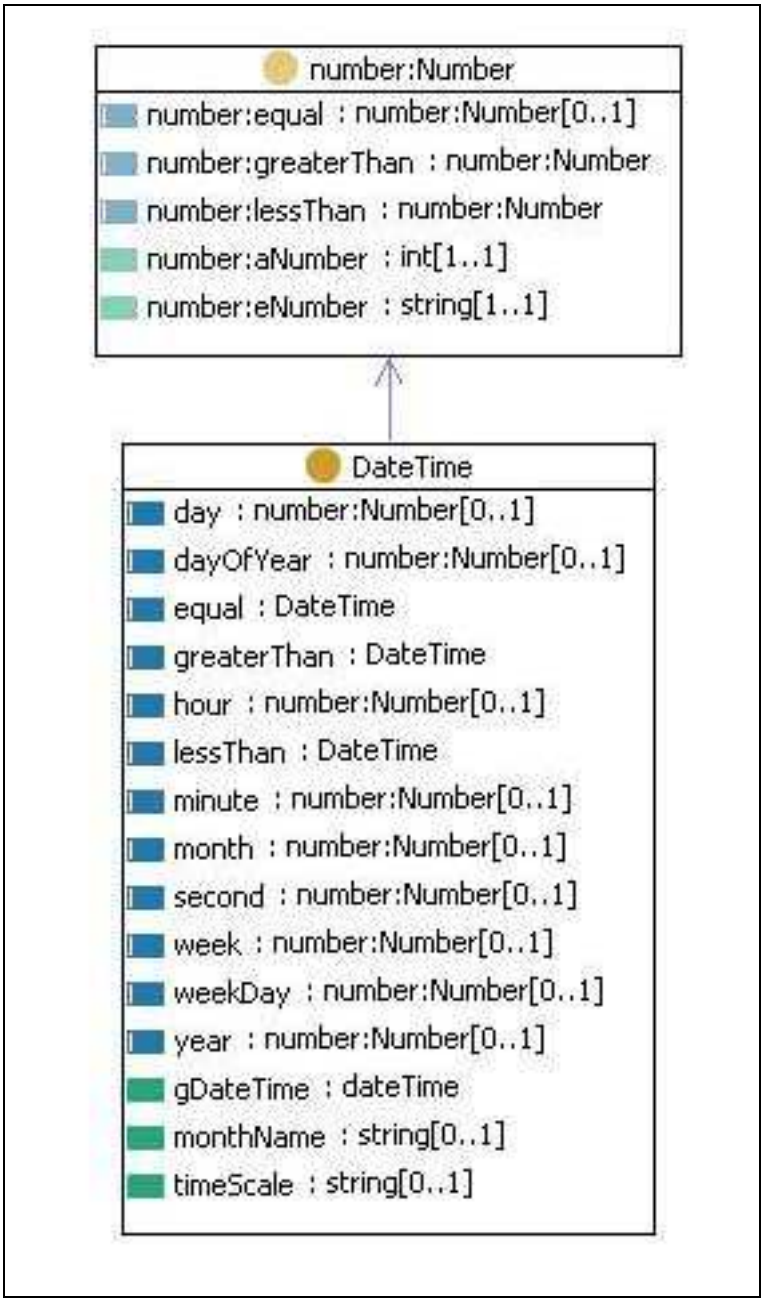

Figure 2 Sample cell model for Date/Time ontology

3.Time Ontology

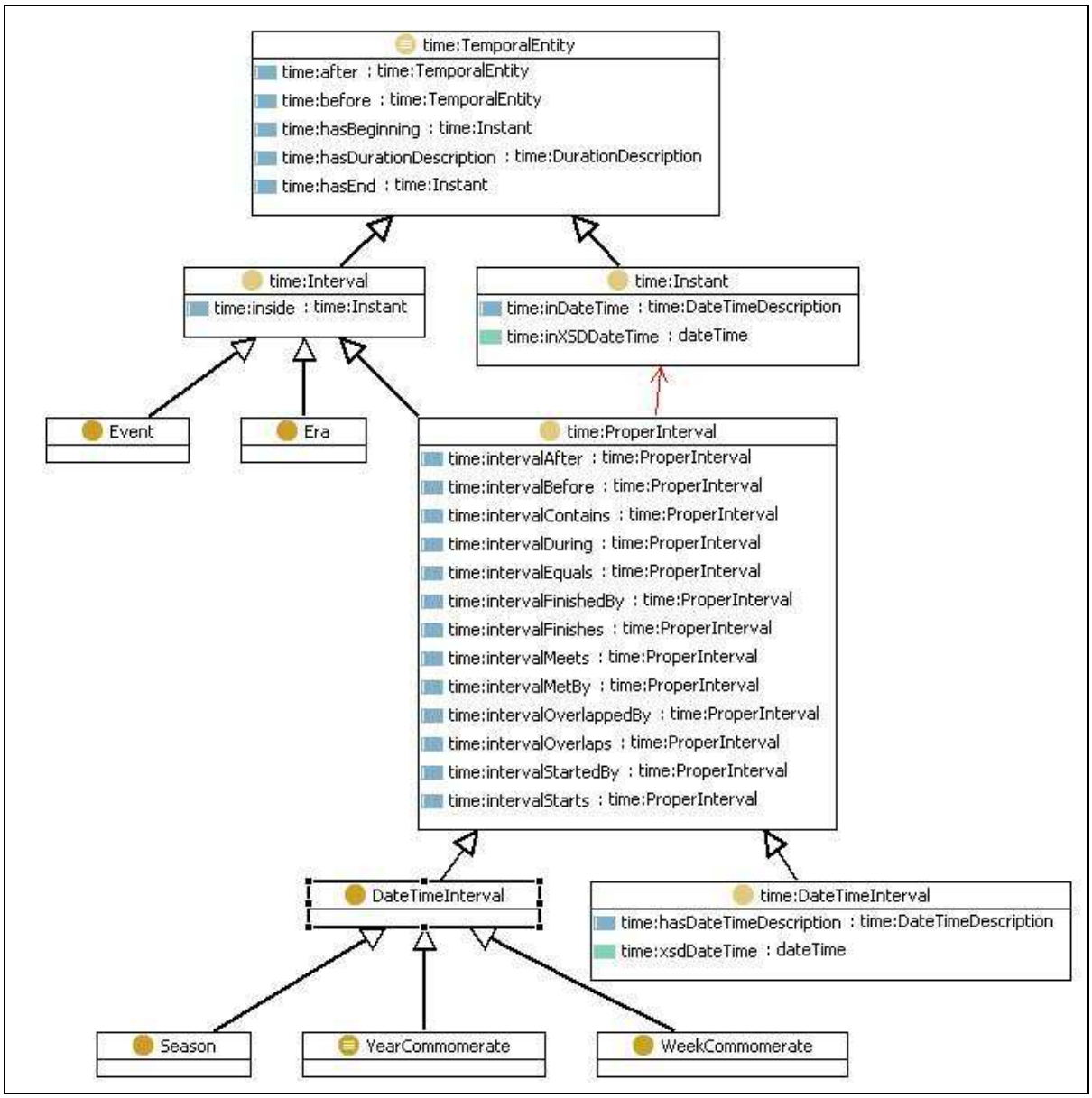

Figure 3 Sample cell model for Time ontology

4. Creation/Creator Ontology

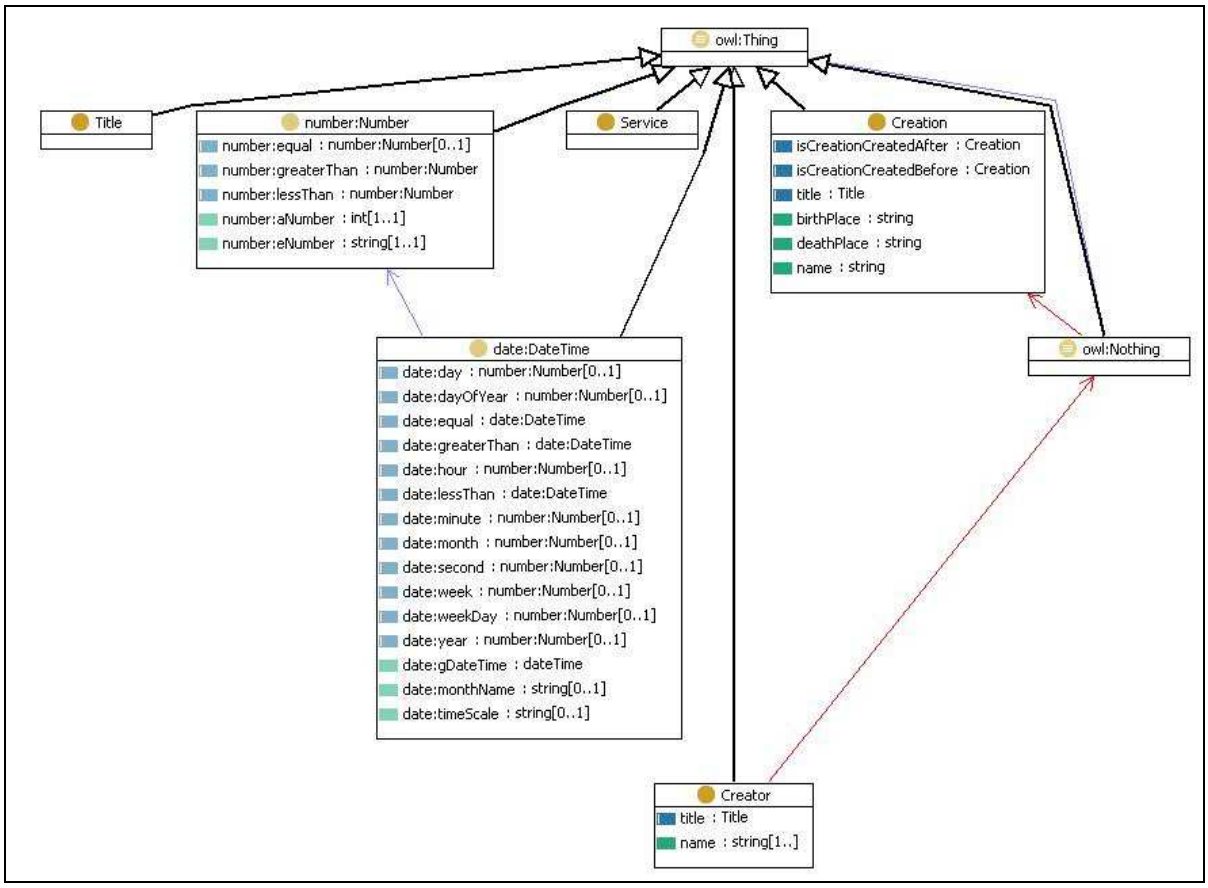

Figure 4 Sample cell model for Creation/Creator ontology

5. Feast Ontology

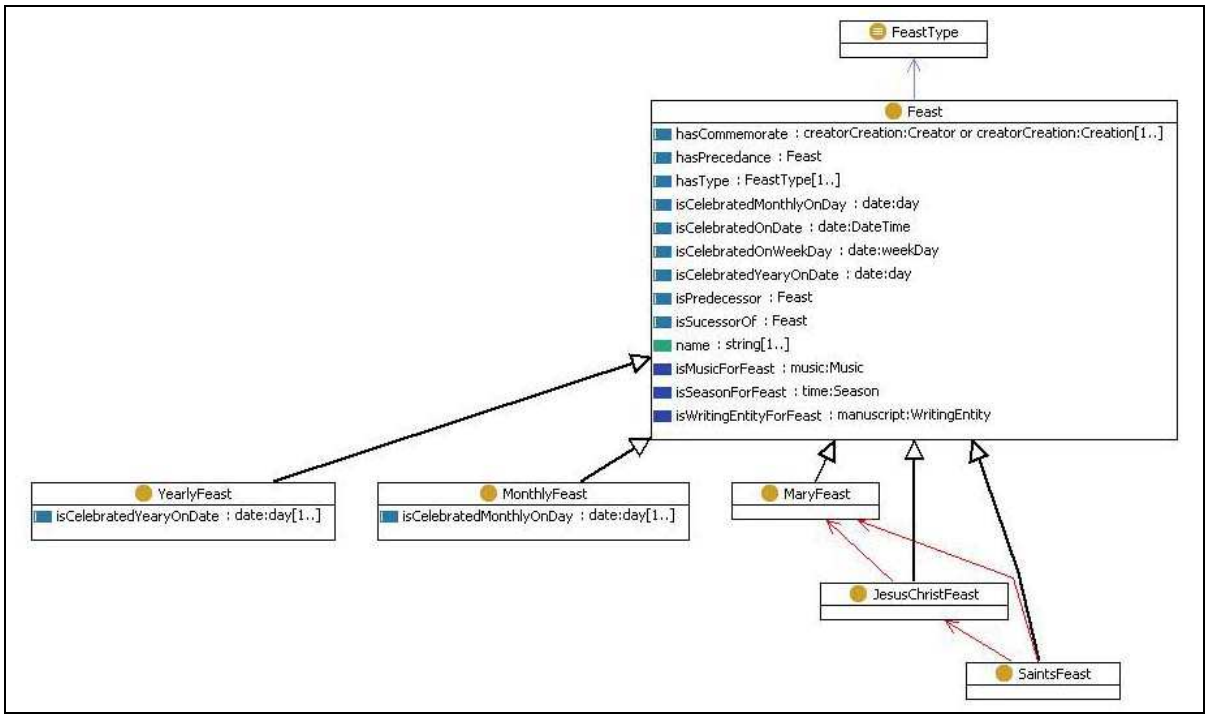

Figure 5 Sample cell model for Feast ontology

6 Manuscript Ontology

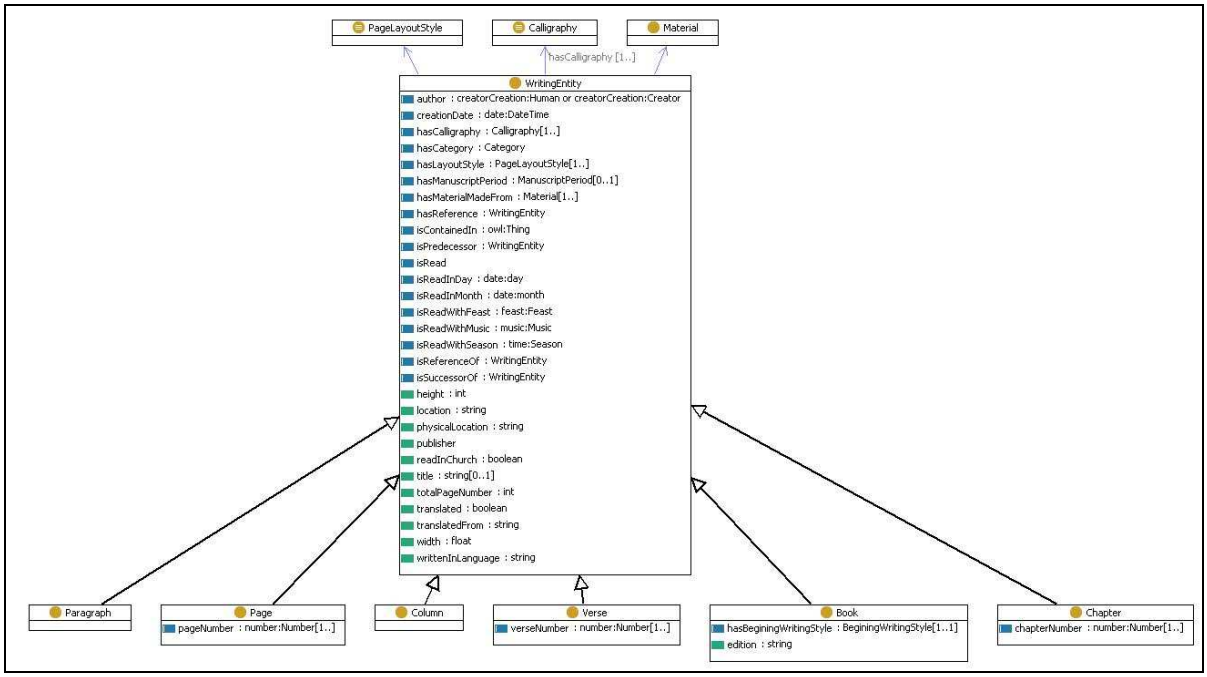

Figure 6 Sample cell model for Manuscript ontology

7. Music Ontology

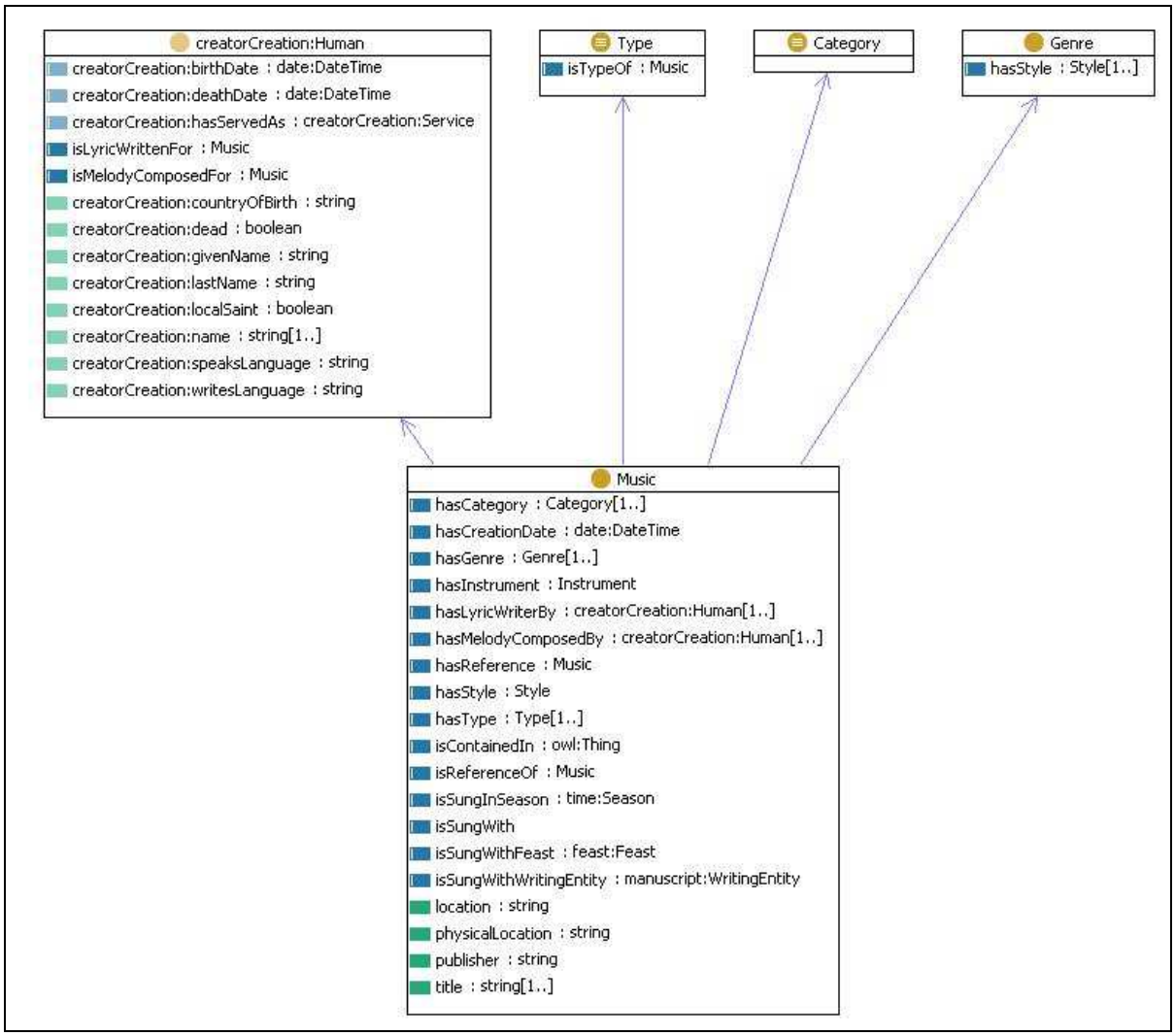

Figure 7 Sampl cell model for Music ontology

8. Art Ontology

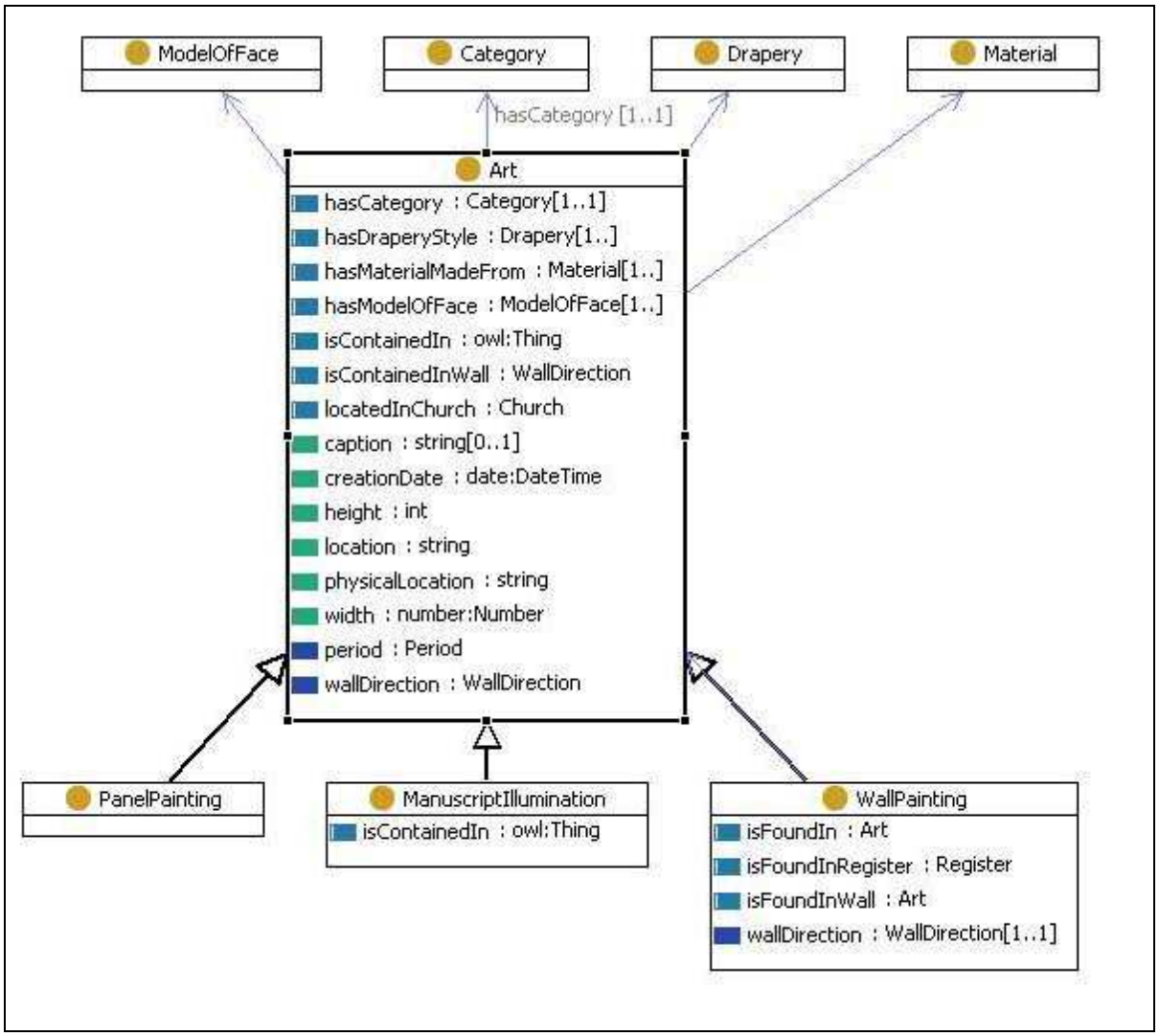

Figure 8 Sample cell model for Art ontology