Semantic data model on knowledge sharing of cultural heritage sites: poompuhar and use case

Abstract

Among the ancient cities and ports of Tamil Nadu, Poompuhar is one such historic and coastal port that emerged with the increasing maritime trade of the early Chola kingdom. The ancient trade town and the busy port of Poompuhar symbolize the Tamil culture and civilization up to 200 CE. The city was destroyed and washed away by big shore waves during 500 AD. The submerged parts and destruction remains scattered are identified in onshore and offshore excavations around the coastal lines of Bay of Bengal in Tamil Nadu. The information of ancient port city are found in various sources such as archaeological evidence, historical references, coastal erosion data and sangam Tamil literature. In this paper a methodology is presented to build the semantic representation of the Poompuhar port city integrating heterogeneous data to create a knowledge base by mapping and associating related entities. The knowledge base is created using CIDOC CRM the cultural heritage ontology to represent Poompuhar events digitally. The experimental results of the created Poompuhar ontology are verified exploring the submergence of Poompuhar use cases for onshore and offshore excavations through knowledge graph.

Keywords: CIDOC-CRM, Ontology, Cultural heritage, Poompuhar Archaeological explorations, Semantic web

1 Introduction

Around 2000 years ago, the ancient port city Kaveripoompatinam or Poompuhar was established by the Chola dynasty which is one of the ancient cities in Tamil Nadu and was the capital located at the confluence of the Cauvery river and sea. The description of the port city are found in heterogeneous sources such as literature evidences, Patinapalai, Manimegalai, Geo Archeological coastal line research data sources, data from land excavation and seashore exploration and from scientific academic research sources. The port has trade link connections with different continents and sea routes like Rome, Arabia. Many Asian ports are mapped to current geolocation from west Bengal (tamralipati – mentioned in the literature), Orissa (palur – identical terminologies found in literature) anchored to kaveripoompatinam port. The ancient port city poompuhar connected all trading countries and the coastal line of Poompuhar lies in the district of Nagapattinam Karaikal, Mayiladurai, Sirkali, Taragambadi, Chennai, Parangipettai, and Cuddalore. The port known for its mysterious disappearance was found buried in sea turbulence in 500 AD. The most ancient clay sculptures and minarets found in the Poompuhar are identified through excavation and reported in literatures. The submergence of Poompuhar are researched by various approaches and the reason of submergence of Poompuhar were presented. The evidence of excavation studies based on data from satellite images, real-time kinematic surveys, shoreline data of coastal zone stated that continuous change in sea level leads to the shift of submerged poompuhar. The deltas of river Cauvery, viz. delta – A, delta – B, and delta – C were formed during the time of the tectonically induced convex coastlines of the region, due to the continuous changes in the sea level and interconnected land-ocean interactions.
Locations of the coast were moved to other coastline regions delta – B to C on period. The author has pointed that the original Poompuhar – 1 as delta A which is located about 30 kilometres east of Kaveripooppatinam stated moved around four times due to the rising sea level. They have also estimated that the structures found in the Poompuhar – 1 harbour would have been constructed around 11,000 – 15,000 years ago. The patterns and layout of the structures found in the other ancient harbours around the world were found similar to be as found in the Poompuhar excavations.

Cultural Heritage sites are pride for the country. The ancient Poompuhar port details when represented digitally will transfer the culture and tradition to future generations. Knowledge on the cultural heritage of Poompuhar need to be mapped and integrated with disparate data sources.

Semantic technologies are used to integrate heterogeneous data and where ontologies are standard framework used to represent related concepts. In this work a semantic knowledge base is created as Poompuhar ontology to integrate information of the ancient port city. CIDOC-CRM is a standardized ontology model for cultural heritage devised with 99 classes and 198 properties to symbolize cultural-related tangible and intangible concepts. The proposed Poompuhar ontology is created by mapping the existing CIDOC ontology to relate knowledge of submerged Poompuhar.

The paper is organized section-wise as follows: the archaeological excavations of the ancient port city Poompuhar submerged evidence, and need of knowledge model are briefed in section 1. Semantic web literature survey related to cultural heritage data, ontology mapping extending to CIDOC CRM with standards are presented in section 2. The methodology and architecture for relating CIDOC entities to Poompuhar ontology are described in section 3. The semantic relationship of the Poompuhar ontology verified with use case to explore knowledge on submergence of Poompuhar as experimental result in section 4. Finally, the conceptual data model of cultural heritage Poompuhar is concluded in section 5

2 Literature Review

This section focuses on the reviews specifically on construction of knowledge model relating with CIDOC CRM standards to manage data integration problems within the field of cultural heritage. This review approach outlines the research carried out across in various disciplines using existing standards of CIDOC CRM for extending the domain data model to build knowledge sources. The data challenges of diverse data representation formats, data standards, ambiguity of context faced are addressed using formal ontology for knowledge engineering for data integration.

Global ontologies were developed with a methodology for representing archaeological context to map evidence with timeframe using CIDOC specifications for Knowledge management in cultural heritage. The CIDOC – CRM and FRBRoo ontology is related in various domain to address the issues of data complexity in data structure with optimized data model.

The study on excavation of submerged Poompuhar locations are explored based on the shift of Cauvery delta and its tectonic movement to prove the detection on submerged harbour with GEBCO, MBES data, and underwater profile survey. The authors have used literary works and geo archaeological evidence, sedimentary evidence from archaeological sites and chronological view on submerged ancient port city kaveripoopattinam (poompuhar) to identify variation in shoreline, explore cauvery delta movements with geo coordinates.
The domains of Archaeology, Architecture, Cultural heritage, history, library, archival sciences, museology, preservation science have extended their ontology model with CIDOC conceptual reference\textsuperscript{1,13,14}. The semantic applications for publishing and visualizing linked data for museums\textsuperscript{15} are discussed using CIDOC CRM as domain knowledge representation.

3 CIDOC Ontology – A View

CIDOC Conceptual Reference Model (CRM) defines the formal structure of the cultural objects and their implicit and explicit relationships for Museums. CIDOC CRM was developed by the International council of the museum and the International council of documentation to build one common metadata standard and formal ontology for solving information management problems for museum data. CIDOC CRM was recognized as an ISO standard in 2006. The model has temporal entities gathered around historic information and events related with spatio temporal information. The CIDOC CRM contains formal ontology with global schema to integrate domain-specific entities relating to global standards. The present CIDOC – CRM ontology contains 99 classes and 198 properties\textsuperscript{17,18}. The CIDOC – CRM can be extended with formal ontologies like FRBRoo to represent bibliographic information, PreSSoo to document and relate bibliographic information with serials. The CIDOC –CRM are extended as specified: CRMinf the global schema for integrating metadata of different domains with cultural heritage CRMsci is used to map scientific observations and measurements. CRMdig is used to represent 3D modelling data, CRMarchaeo is used to document on excavation objects. CRMgeo is used in the domain of Geophysics for representing geolocation with base compatible standards\textsuperscript{18}.

4 Architecture and Methodology

This section describes the construction of data architecture to create a knowledge model to digitize Poompuhar as illustrated in Figure 1. Conceptualization of Poompuhar requires mapping information related to the culture, civilization, and landscape of the ancient city. The data source to represent Poompuhar are extracted from literature sources found in Sangam Tamil literature and other archaeological sources such as artefacts, inscriptions in pillars of the temple, and copper coins to conceptualize cultural knowledge base. Information on submergence of Poompuhar denoted as ‘sea submerged Poompuhar due to repeated floods, neo-tectonic activity, tsunami, sea incursions, changes in ecology, invasions, natural calamity, changes in climate, deforestation and other reasons like epidemic Indus civilization (300 BCE) are gathered from a literature study on the geological landscape to integrate into the knowledge base.

The gathered domain knowledge is mapped to the global standard called CIDOC CRM\textsuperscript{17} (Committee for DOCumentation Conceptual Reference Model) to describe the knowledge base to extract knowledge of Poompuhar port city.
Knowledge Graph : Creation

Step 1: Data Acquisition: Acquisition of Cultural Heritage data from heterogeneous data sources (*.txt, *.docx, *.html, *.shp) as shown in Figure 1 & 2.

Step 2: Data Cleaning & Data Standardization phase is carried out to preprocess data to remove inconsistency, transformation and retrieving domain entities.

(i) Identifying individual entities using Named Entity Recognition (NER) as Port, Ruler, King

(ii) Taxonomy: Domain conceptualization of Poompuhar entities in hierarchical structure as shown in Figure 3.
Step 3: Creation of Knowledge Model: Construction of ontology by representing concepts as Classes, Properties of both data and object as Relations, instance data as attributes as individuals as shown in Figure 4.

(iii) Ontology terminologies to associate and relate entities of cultural heritage\textsuperscript{19,25}

Step 4: Exporting knowledge representation in machine readable form as .RDF

Step 5: Visualize knowledge as knowledge graph
4.1 Methodology

The methodology for exploring ancient city Poompuhar is carried as two phases. In the first phase entities conceptualized from archaeological and literature data sources acquired as given in Figure 1 are mapped with CIDOC CRM entities directly and indirectly. In Phase 2 CIDOC CRM properties types and axioms of Poompuhar entities are related with the events of culture, submergence of city-specific to timeline.

4.1.1 Phase 1: Direct and Indirect entity mapping of Poompuhar with CIDOC CRM

The Archaeological and Geologist evidence of submergence of Poompuhar associated with landscape, culture, and manmade objects are mapped with temporal events, timelines, evidence from inscriptions directly using CIDOC CRM classes and properties as listed in Table 1.

Table 1. Direct data mapping of domain entities (Poompuhar)

<table>
<thead>
<tr>
<th>Entities</th>
<th>Properties</th>
<th>Concept Domain Mapping</th>
<th>Description</th>
</tr>
</thead>
</table>
| E2 – Temporal Entity | P4 – has time-span | • Civilizations   
• The timespan of the ancient port Poompuhar   
• Cauvery delta movement   
• Secular Literature   
• Religious literature   
• Archaeological sources   
• Foreign notices - Traders | The ancient port Poompuhar submerged due to sea-level rise 1000 years ago (E4 – Period)   
The Buddha statue excavation carried out (P14) at offshore Champapathi Amman temple (DPE1) |
| **E34 – Inscription** | P3 – has a note | • Temple pillars  
• Copper coins  
• Monuments  
• Stupas  
• Viharas  
• Chaitya  
|----------------------|-----------------|-------------------------------------------------|-------------------------------------------------|
| **E52 – Time-Span** | P170 – defines time by | • Period  
• Capital city  
• Chola dynasty  
• Geographical range  
• Sources  
• Civilization nature | The time span of the ancient city poompuhar (E52) was established by the Chola dynasty during the Sangam period (300 BC to 300 AD) E59 – Time primitive value |
| **E55 – Type (superclass of) – (E54) – Dimension | **E58 – Measurement Unit** | P90 – has value | The 36.25 x 18.75 x 7.5 cm (E58) height brick structure of the Buddha vihara |
| **E4 - Period** | has identified | • Artifacts  
• Objects  
• Urns | The traces of submerged poompuhar evidence identified are mapped through the property (P35) to the class (E4) around the nearby location of Cauvery. |
| **E18 – Physical thing** | P13 – was destroyed | • Rock cut architectures  
• Palaces  
• Cities  
• Towns  
• Monarchies | Sembian (E21 – Person) was a mythological Chola king who destroyed (P13) the fortress |

A. Mapping of Entity Evidence with CIDOC Subclass for Inscriptions:

Domain Knowledge: The ‘inscriptions’ related to port city kaveripoopatiminam found in ancient literature are mapped with CIDOC as described in Table 2 and shown in Figure 6.

**Table 2. Poompuhar entity mapping with CIDOC subclasses**

<table>
<thead>
<tr>
<th>Entities</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>E31 Document</td>
<td>Port City Evidence: Inscription Describe in Literature</td>
</tr>
<tr>
<td>E32 Authority Document</td>
<td>Evidence identified through Archaeological Excavation</td>
</tr>
</tbody>
</table>
E55 Type | Objects Identified through AR Excavation mapped as Man-made, natural
---|---
E16,E54,E60 | Measurements of objects identified for their measurements, dimension, scale and value

Figure 6. Direct Entity Mapping: Digital Poompuhar Ontology (CIDOC – CRM concept: Conceptual Object)

4.1.2 Indirect Mapping by the creation of new classes

CIDOC- CRM does not have relevant classes to be mapped with the identified evidence in the archaeological excavation carried out at offshores of Poompuhar and beneath sea level, New CIDOC CRM entities are created as new classes to represent Poompuhar with prefix as DPE(Digital Poompuhar Entities) and corresponding properties with the prefix DPpro (Digital Poompuhar property). The created classes and properties are used to map the domain knowledge of research experts for conceptualizing submergence of Poompuhar based on geological studies indirectly with CIDOC- CRM as represented in Table 3.

<table>
<thead>
<tr>
<th>Created Entities</th>
<th>Object Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DPE2: Evidence</strong></td>
<td>DPpro1 – has suggested (created)</td>
<td>To map, the archaeological evidence and literary work to state natural calamities that occurred at the Poompuhar region.</td>
</tr>
<tr>
<td><strong>DPE3: Coast Line Town</strong></td>
<td>DPpro2 – border of</td>
<td>To map the current location of the Nagapattinam district and other districts of submerged Poompuhar</td>
</tr>
</tbody>
</table>
DPE4: Place (E53)Name

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<thead>
<tr>
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<td>Linguistic object (E33)</td>
<td>represents (P138)</td>
<td>Explored evidence found in epics (Pattinapalai) are mapped with Physical man-made things (E24) identified during archaeological excavation such as excavated burnt bricks.</td>
</tr>
<tr>
<td>Depicts (DPpro)</td>
<td>To Map civilization and culture which explored in various languages.</td>
<td></td>
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CIDOC-CRM entities

<table>
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<th>Properties</th>
<th>Created Classes Property Mapping</th>
</tr>
</thead>
<tbody>
<tr>
<td>E33: Linguist Object</td>
<td>P72: has language</td>
</tr>
<tr>
<td>E90: Symbolic Object</td>
<td>has inscriptions</td>
</tr>
<tr>
<td>E24: Physical Man-made thing</td>
<td>P45: consists of</td>
</tr>
</tbody>
</table>

B. Property mapping with domain entity for representing coastal erosions:

Domain Knowledge: The archaeological evidence and literary works that described the repeated occurrence of natural calamities in the Poompuhar (coastline town) region are mapped as listed in Table 4. The relevant classes and properties to describe the domain knowledge, as shown in Figure 7 are unfound in CIDOC-CRM, hence new class ‘coastline town’ and property are mapped with CIDOC.

Table 4. Poompuhar property mapping with domain entities

<table>
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</tbody>
</table>
Phase 2: Property types and axioms related to entities

Description of Poompuhar ancient port city requires functional mapping of multiple related entities through property relations, property restrictions and axioms to infer knowledge. The relations identified in CIDOC to map Poompuhar Ontology entities are listed in Table 5.

Table 5. Poompuhar Ontology Property Mapping

<table>
<thead>
<tr>
<th>Property relations</th>
<th>Types</th>
<th>Axioms</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP:found_yields</td>
<td>transitive property</td>
<td>Yields (evidence) found in more than one place</td>
</tr>
<tr>
<td>DP: Cauvery delta</td>
<td>functional property</td>
<td>islocatedIn connects a city to a single country(a city may not be located in two countries)</td>
</tr>
<tr>
<td>Inverse Property of DP:ContainsExplorations</td>
<td></td>
<td>(River Cauvery delta movement along with the changes of sea level contains explorations of submerged puhar)</td>
</tr>
<tr>
<td>DP: nearby cities</td>
<td>as a property chain</td>
<td>Connects a city to the neighboring countries of the country to establish trade links and culture sharing</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Property value restriction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DP: City</strong></td>
</tr>
<tr>
<td><strong>DP: Country</strong></td>
</tr>
<tr>
<td><strong>DP: locatedIn</strong></td>
</tr>
<tr>
<td><strong>hasValue</strong></td>
</tr>
<tr>
<td>The ancient port city located in Kaveripoornpatinam, property value restriction depicts as <strong>DP: City and DP:locatedIn.</strong>  <strong>DP: City a DP:locatedIn.</strong>  <strong>DP:portcity a owl:Class ; rdfs: subclassOf DP:City; rdfs: subclassOf [a owl:Restriction; owl:onProperty DP:isLocatedIn; owl:hasValue DP:Kaveripoornpatinam].</strong></td>
</tr>
</tbody>
</table>

Knowledge model of Poombuhar port city created as Poombuhar ontology mapped with CIDOC CRM is shown in Figure 8. The ontology is related with literature and archaeological evidence associating multiple entities and natural events to infer knowledge on evidence of port city, richness of cultural heritage mapped with spatiotemporal events, trade links, submergence of Poombuhar, objects identified at various timelines. The created ontology consist of 147 classes, 13 Object properties, 5 Data Properties and 34 Individuals. The use cases for results and discussions are inferred from the Poombuhar Ontology.
Results and Discussion
This section discusses use case to extract the related knowledge of Poompuhar port city events caused in offshore and onshore sites using Poompuhar ontology.

Offshore Excavations - Archaeological Evidences

Digital Poompuhar evidence is categorized under three variant sources archaeological, geological and literary parts. The offshore excavation of Poompuhar data are extracted from archaeological evidence on ancient artefacts include pottery, jewellery made of beads and terracotta, copper objects like vessels, rings, bangles, wires, and a rattle, stone objects like pestles for grinding grain, iron knives, nails, brick figures, copper coins. The objects identified through archaeological excavation described in literature epics are integrated and related with geological locations mapped to districts in the Poompuhar ontology as knowledge base.

Usecase 1: Integrated Information: Archaeological Evidence on Poompuhar Excavation Objects

(i). Knowledge mapping: Terracotta ring wells

The evidence of terracotta ring wells, square copper coins, shaped brick structures, wharves, brick buildings, boat jetties, and water reservoirs of excavated objects related with the information cited in literature documents of Ahananuru, Purananuru, Pattinapalai, Silappadikaram, Manimekalai\(^6\) are integrated and mapped with offshore locations Kilaiyur, Vanagiri, Santaththi Amman Temple is shown in Figure 9 the knowledge graph. The poompuhar ontology devised is also integrated with information extracted from literature review of geological studies related to offshore excavation location\(^{22, 23}\).
Figure 9. Knowledge Inferred –Evident Terracotta ring well mapping

(ii) **Knowledge mapping: Buddha statue**

In the year 1927 (8th century) Bothi Sathuvam Thuyva called gold plated Buddha statue⁶, wharves were identified near Melaipiru of Nagapattinam district. The available evidence of excavated Buddha statue timeline mapped with period and spatiotemporal location. The integrated knowledge inferred from Poompuhar ontology is shown in Figure 10.

![Figure 10. Knowledge Inferred -Evident mapping with its timeline](image)

**Use case 2: Integration of Sangam Literatures of Poompuhar Evidence**

The Sangam literature and epics elaborated the whole town planning systems of ancient poompuhar, the cited evidence from the 5th silappadikaram chapter and pattiappalai by the poet kadiyalur uruthiran kannanar⁶. The glory of poompuhar and the life achievements of the king thirumavalavan known as karikala cholan is briefed for 218 lines in the poem as segments. Knowledge inferred from Poompuhar ontology mapping the history of poompuhar from Sangam Tamil and epic literary evidence is shown in Figure 11 (knowledge graph)

![Figure 11. Knowledge inferred for mapping Literature with rulers with poetry](image)

(i) **Mapping of history of rulers described in poetry**

The Chola king named Musunkunda Chakravarthy, ruled from the city Karur (present) and ended with the destruction of the fortress through other mythological king Sembian found in the literature evidence of purananuru 39²⁴ – Thugacil Aerindha Thodithol Sembian and other literature cirupanarruppadai 74-75: Thoongu aeiil aerintha thodi vilagu thadakai naada nallisai natroar sembian²⁴ related with poet information. The knowledge inferred from Poompuhar ontology mapping all related entities is shown in Figure 12.
(ii) Knowledge Mapping on Exploration of ancient town Poompuhar with the epic Silapathigaram

The ancient town Poompuhar is surrounded by five Mandrams, four gardens, sixteen temples (approx.) as mentioned in the epic Silapathigaram listed with town layout containing avenues, streets, mansions, residences of foreign merchants, gardens, market places, traders, workshops, well-laid streets occupied by yavana sailors, overseas traders, weavers, silk traders, grain merchants, jewellers, gem makers. The domain mapping of Poompuhar temples, gardens, and Mandrams extracted from literature inferred as knowledge graph using Poompuhar ontology is shown in Figure 13.

Onshore Explorations - Geological Evidences

The Onshore exploration of Poompuhar below sea level based on scientific studies in the literature are integrated into Poompuhar Ontology.
Usecase 3: Geological Evidence for Poompuhar region through Explored structures under the ocean

Mapping Poompuhar Submergence onshore evidence with the literature

The ancient port city poompuhar submergence cited as “kadalkol” [swallowed by the sea] and in the epic mentioned ‘theevaga saanthi saeiyaa naalun kaval maanagar kadalvayir puguvoom’ (manimegalai 24:62-63) comprise both spiritual literary evidence from epics and scientific geographical onshore explored evidence from coast cairn circles, urn burials (Suryakundam, Somakundam, U shaped Structure under the water depth of 8-25 m in the ocean Bay of Bengal near the shoreline (sea submergence – ancient port - puhar), sand sediments, shoreline delta movement summarised that submergence of the ancient city happened due to natural calamities tsunami, floods, coastal erosions or sea incursions. The recent study with past shoreline data collected from general bathymetric chart of the oceans (GEBCO) presented by the author traced the existence of submerged poompuhar with geographical evidence. Presently the poompuhar location exists with six small villages they are Sayavanam / Thirusaikadu, Pallavanisvaram, Melapperumpallam, Keelaperumpallam, Keezaiyur, and Vanagiri.

The classified shoreline data mapped to Tamil epics extracted from Poompuhar ontology knowledge base is shown in Knowledge graph Figure 14, 15.

Figure 14. Knowledge inferred - Mapping with shoreline data

Figure 15. Knowledge inferred - Mapping with Spatial Coordinates
Conclusion

In this paper an integrated data model was designed using ontology for ancient port city Poompuhar by integrating heterogeneous data from archaeological, literature and geological evidence. The existing properties and classes of cultural heritage knowledge model CIDOC-CRM are reused with additional new domain entities and properties to map the events of the submergence of Poompuhar. CIDOC entities are mapped directly for relating events with evidence from literature and archaeology. Indirect mapping is done to related events that occurred onshore using the new domain entities created. The experimental result are explored as knowledge graphs inferred from the Poompuhar knowledge base for various use cases related to submerged Poompuhar excavated evidences. The excavation equipment and devices are not described in the mapping which is the limitation and will be updated in the future version of Poompuhar Ontology.

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Conflict of Interest

The authors declare no conflict of interest.

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