

Semantic data model for knowledge representation and dissemination of cultural heritage site, Poompuhar

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Among the ancient cities and ports of Tamil Nadu, India, Poompuhar is a historical 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 AD 500. The submerged parts and scattered destruction remains have been identified in onshore and offshore excavations around the coastal lines of the Bay of Bengal in Tamil Nadu. Information on the port city can be found in various sources, such as archaeological evidence, historical references, coastal erosion data and Sangam Tamil literature. Here, a methodology is presented for a semantic representation of Poompuhar port city, integrating heterogeneous data to create a knowledge base by mapping and associating related entities. The knowledge base has been created using CIDOC CRM to represent Poompuhar events digitally. The experimental results of the ontology are verified exploring the submergence of Poompuhar use cases for onshore and offshore excavations through a knowledge graph.

Keywords: Archaeological explorations, cultural heritage, knowledge graph, ontology, semantic data.

AROUND 2000 years ago, the ancient port city of Kaveripoompattinam or Poompuhar, Tamil Nadu, India, was established by the Chola dynasty is the capital city located at the confluence of the Cauvery river and around estuaries. This port city can be found in various sources such as literature evidences¹⁻⁴ in *Silpathikaram*, *Patinapalai*, *Manimegalai*⁵, geo-archeological coastal line research data sources, data from land excavation and seashore exploration, as well as from scientific research⁶.

The ship sailed from Rome and Arabia for trade. It travelled to various Asian ports from Tamralipati to Palur as mentioned in the literature⁷. When mapping the places with current geolocation, the terminologies were found identical to West Bengal and Odisha. Finally, the ships were anchored at Kaveripoompattinam port. The ancient port city of Poompuhar connected all trading countries and its coastline covered the districts of Nagapattinam, Karaikal, Mayiladurai,

Sirkali, Taragambadi, Chennai, Parangipettai and Cuddalore in the present-day Tamil Nadu².

The port known for its mysterious disappearance was found buried due to sea turbulence in AD 500 (ref. 8). The ancient clay sculptures and minarets found in Poompuhar have been identified through excavation and reported in the literature. Its submergence has been researched using various approaches³.

The evidence from excavation studies based on satellite images, real-time kinematic surveys and shoreline data of coastal zones revealed that continuous sea level changes led to a shift of the submerged port city⁹. The deltas of the 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 continuous changes in the sea level and interconnected land-ocean interactions¹⁰. Over the period, the submerged Poompuhar port city location moved from coastline region Delta B to Delta C. Doerr *et al.*¹¹ reported Poompuhar-1 as Delta A which is depicted as the first submergence of Poompuhar port city at a particular location and moved four times to other locations due to the sea level rise and sea erosions. It has been estimated that the structures found in the Poompuhar-1 harbour may have been constructed around 11,000–15,000 years ago^{10,11}. The patterns and layout of the structures found in other ancient harbours around the world were similar to those of the Poompuhar excavations.

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

Semantic technologies are used to integrate heterogeneous data and ontologies are the standard framework used to represent related concepts. In this study, a semantic knowledge base has been created as Poompuhar ontology to integrate information about the ancient port city. The International Committee for Documentation (CIDOC)–Conceptual Reference Model (CRM) is a standardized ontology model for cultural heritage devised with 99 classes and 198 properties to symbolize culture-related tangible and intangible concepts. The proposed ontology was created by mapping the existing CIDOC ontology to relate knowledge of submerged Poompuhar.

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Literature review

We focus on the reviews specifically dealing with the construction of the knowledge model related to CIDOC CRM standards to manage data integration problems within the field of cultural heritage. We outline research carried out across various disciplines using existing standards of CIDOC CRM for extending the domain data model to build knowledge sources. The challenges of diverse data representation formats, data standards and ambiguity of context have been addressed using formal ontology for knowledge engineering for data integration¹¹.

The global ontologies like CIDOC CRM for representing cultural heritage are mapped with archaeological evidences on a time frame for knowledge management in the domain cultural heritage¹²⁻¹⁴. To address the data complexity issues in data structure and for optimized data models, CIDOC CRM and FRBRoo are used¹⁵.

The study on the excavation of submerged Poempuhar locations was done based on the shift of the Cauvery delta and its tectonic movement, to prove the detection of the submerged harbour with GEBCO, MBES data and underwater profile survey¹⁶. We have used literary works and geo-archaeological evidence, sedimentary evidence from archaeological sites and a chronological view of the submerged ancient port city to identify variation in shoreline⁴ and explore the shift of the Cauvery delta with geo-coordinates^{7,9}.

The domains of archaeology, architecture, cultural heritage, history, library, archival sciences, museology and preservation science have extended their ontology model with CIDOC conceptual reference^{4,6,17}. The semantic applications for publishing and visualizing linked data for museums have been discussed using CIDOC CRM as the domain knowledge representation¹⁸.

CIDOC CRM ontology

CIDOC CRM defines the formal structure of cultural objects and their implicit and explicit relationships for museums. It was developed by the International Council of Museums 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 involving historical information and events related to spatio-temporal information. CIDOC CRM contains formal ontology with a global schema to integrate domain-specific entities relating to global standards. The present CIDOC CRM ontology contains 99 classes and 198 properties^{19,20}. It can be extended with formal ontologies like FRBRoo to represent bibliographic information and PreSSoo to document and relate bibliographic information with serials. The ontology can be extended as specified: CRMinf is 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 geolocations with base-compatible standards²⁰.

Architecture and methodology

Figure 1 describes the construction of data architecture to develop a knowledge model to digitize Poempuhar. The conceptualization of Poempuhar requires mapping information related to the culture, civilization and landscape of the ancient city. The data sources to represent Poempuhar have been extracted from the Sangam Tamil literature and other archaeological sources, such as artefacts, inscriptions in temple pillars and copper coins to conceptualize cultural knowledge base. Information on the submergence of Poempuhar denoted as 'sea-submerged Poempuhar' due to repeated floods, neo-tectonic activities, tsunamis, sea incursions, changes in ecology, invasions, natural calamities, changes in climate deforestation, water flow structure change in rivers, and other reasons like declining of Indus civilization by external invasions and epidemics are gathered from a literature study on the geological landscape to integrate into the knowledge base. The gathered domain knowledge was mapped to the global standard CIDOC CRM to describe the knowledge base to extract information on the ancient port city¹⁹.

Knowledge graph: creation

Step 1: Data acquisition – acquisition of cultural heritage data from heterogeneous data sources (*.txt, *.docx, *.html, *.shp; Figures 1 and 2).

Step 2: Data cleaning and data standardization phase was carried out to preprocess data to remove inconsistencies, transform and retrieve domain entities. (i) Identifying individual entities using named entity recognition (NER) as a port, ruler or king. (ii) Taxonomy: Domain conceptualization of Poempuhar entities in a hierarchical structure.

Step 3: Creation of knowledge model: (i) Construction of ontology by representing concepts as classes, properties of both data and object as relations, instance data as attributes and individuals (Figure 3) and (ii) Representation of concepts, properties and instances to relate and associate the ontology terminologies with cultural heritage domain knowledge^{21,22}.

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

Step 5: Visualize knowledge as a knowledge graph.

The methodology for exploring Poempuhar was carried out in two phases. In the first phase, entities conceptualized from archaeological and literature sources (Figure 1) were mapped with CIDOC CRM entities directly and indirectly¹⁹. In phase 2, CIDOC CRM properties, types and axioms of

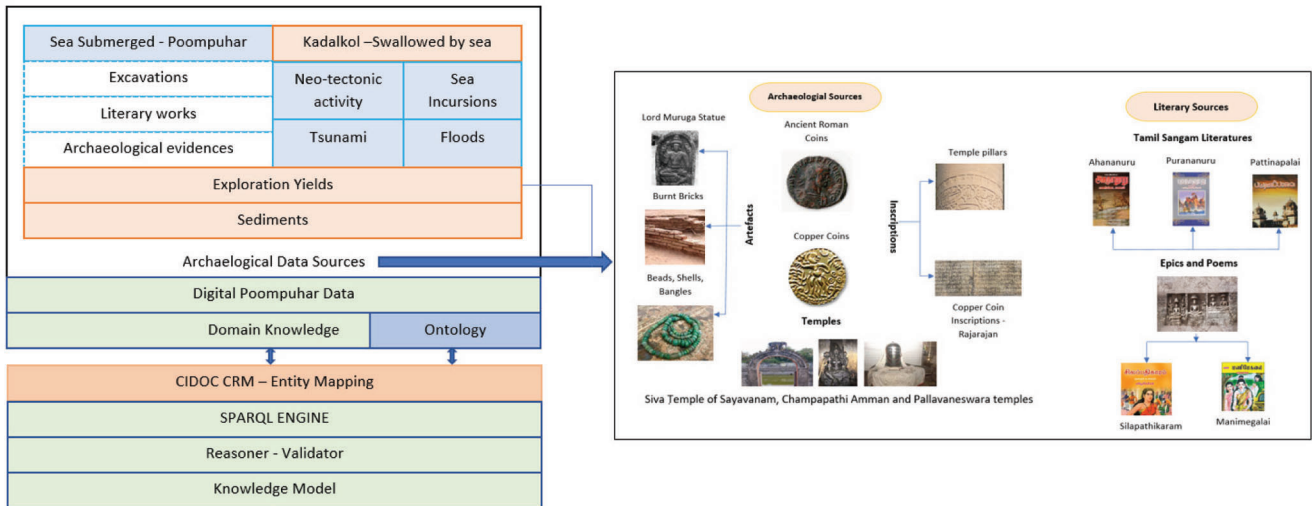


Figure 1. Architecture of knowledge mapping: cultural heritage Poompuhar, Tamil Nadu, India (KM: CHP).

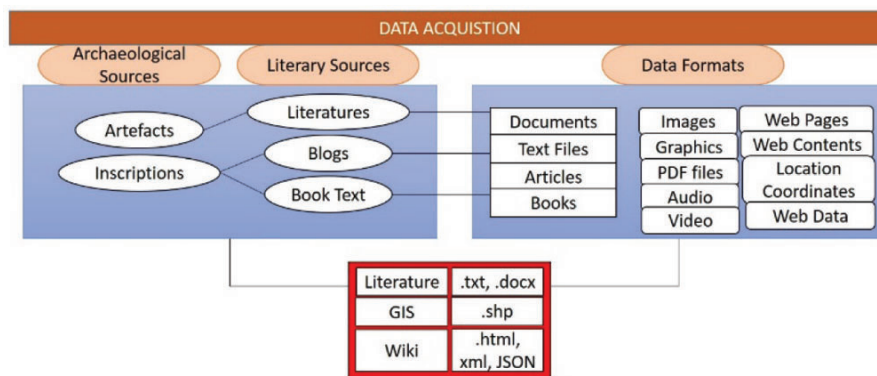


Figure 2. Data acquisition - cultural heritage.

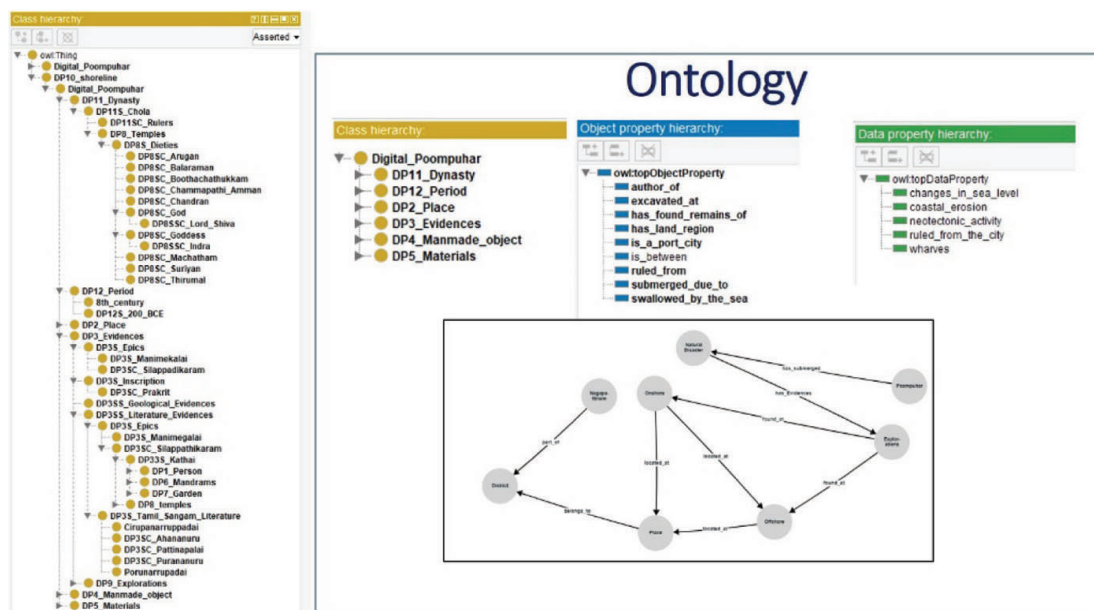


Figure 3. Ontology mapping - cultural heritage.

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Table 1. Direct data mapping of domain entities (Poempuhar), Tamil Nadu, India

Entity	Properties	Concept domain mapping	Description
E2 – Temporal entity	P4 – has time-span P14 – carried out	Civilizations The time span of the ancient port Poempuhar Cauvery delta movement Secular literature Religious literature Archaeological sources Foreign notices – traders	The ancient port of Poempuhar submerged due to sea-level rise 1000 years ago (E4 – period) ³ 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 Languages	Prakrit text is written in stone slab enclosure of a Buddha stupa ²⁵ The text published in <i>Corpus Inscriptorum Indicarum Vol. II pad II</i>
E52 – Time-span	P170 – defines time by	Period Capital city Chola dynasty Geographical range Sources Civilization (Indus valley) nature	The time span of the ancient city Poempuhar (E52) was established by the Chola dynasty during the Sangam period (300 BC to AD 300) E59 – time primitive value
E55-type (superclass of) – (E54) – dimension E58 – measurement unit E4 – period	P90 – has value has identified	Pottery Ornaments Stone and wood Metals Artefacts Objects Urns	The 36.25 × 18.75 × 7.5 cm (E58) brick structure of the Buddha vihara Traces of submerged poempuhar evidence identified are mapped through the property (P35) to class (E4) nearby the Cauvery ³
E18 – Physical thing	P13 – was destroyed	Rock-cut architecture Palaces Cities Towns Monarchies	Sembian (E21 – person) was a mythological Chola king who destroyed (P13) the fortress

Poempuhar entities were related to the events of culture, and submergence of city-specific to timeline.

Phase 1: Direct and indirect entity mapping of Poempuhar with CIDOC CRM: The archaeological and geological evidence of the submergence of Poempuhar³ associated with landscape, culture and artificial objects were mapped with temporal events, timelines, evidence from inscriptions directly using CIDOC CRM¹⁹ classes and properties (Table 1).

Mapping of entity evidence with CIDOC subclass for inscriptions

Domain knowledge: The ‘inscriptions’ related to the port city of Poempuhar found in the ancient literature were mapped with CIDOC CRM (Table 2 and Figure 4).

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 off-shore locations of Poempuhar and below sea level³, New CIDOC CRM entities were created as new

classes to represent the port city with prefix as DPE (digital Poempuhar entities) and corresponding properties with the prefix DP_{pro} (digital Poempuhar_{property}). The created classes and properties were used to map the domain knowledge of research experts for conceptualizing the submergence of Poempuhar based on geological studies indirectly with CIDOC CRM (Table 3)³.

Property mapping with domain entity for representing coastal erosions

Domain knowledge: The archaeological evidence and literary works that describe the repeated occurrence of natural calamities in the Poempuhar (coastline town) region were mapped (Table 4). The relevant classes and properties to describe the domain knowledge, as shown in Figure 5, were not available in CIDOC CRM. Hence a new class ‘coastline town’ and property were mapped with the ontology.

Phase 2: Property types and axioms related to entities

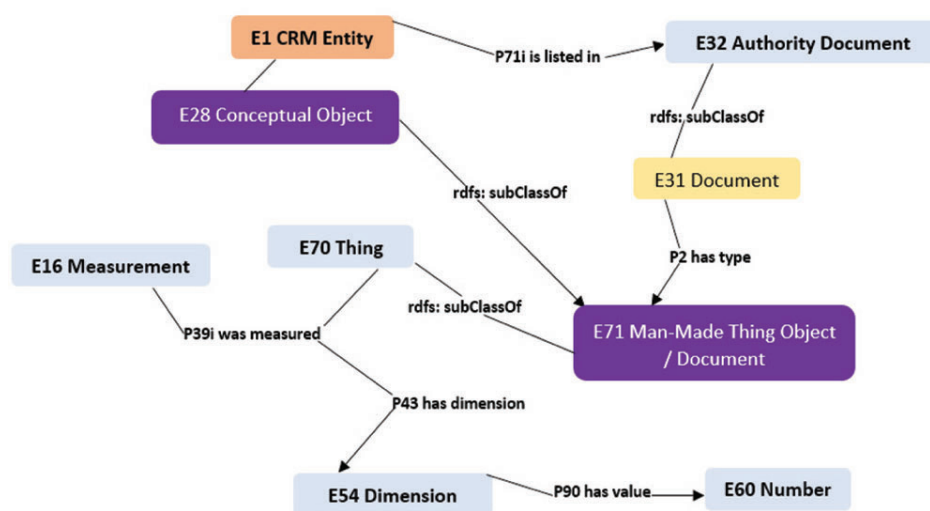
The description of Poempuhar requires functional mapping of multiple related entities through property relations, property

Table 2. Poempuhar entity mapping with CIDOC CRM subclasses

Entity	Description
E31 document	Port city evidence: inscription described in the literature
E32 authority document	Evidence identified through archaeological excavation
E55 type	Objects identified through AR excavation mapped as man-made and natural
E16, E54, E60	Objects identified for their measurements (the structure of the onshore explorations), dimension (the width and depth of the object findings of the Poempuhar), scale and value

Table 3. Indirect data mapping of domain entities (Poempuhar)

Created entity	Object properties	Description
DPE2: Evidence	DP _{pro} 1 – has suggested (created)	To map, the archaeological evidence and literary work to state natural calamities that occurred at the Poempuhar region
DPE3: Coastline town	DP _{pro} 2 – border of	To map the current location of Nagapattinam district and other districts of submerged Poempuhar ³
DPE4: Place (E53) name	DP _{pro} 3 – submerged due to (created)	To map Poempuhar (DPE4) submergence due to (DP _{pro} 3) coastal erosion and other related sea events indirectly using (E53 – name) ³
DPE4: Place (E53) name	DP _{pro} 4 – had yielded	To map the offshore exploration of current geological studies of Poempuhar location Kilaiyur (E53) indirectly (DPE4) using has yielded (DP _{pro} 4) to archaeological evidence (DPE2) ³

**Figure 4.** Direct entity mapping: digital Poempuhar ontology. (CIDOC CRM concept: conceptual object).

restrictions and axioms to infer knowledge²³. Table 5 lists the relations identified in CIDOC CRM to map the Poempuhar ontology entities.

Figure 6 shows the knowledge model of the port city developed as the Poempuhar ontology mapped with CIDOC CRM. The ontology is related to the literature and archaeological evidence associating multiple entities and natural events to infer knowledge on evidence of the port city, the richness of cultural heritage mapped with spatio-temporal events, trade links, submergence of Poempuhar and objects identified at various timelines. The developed ontology consists of 147 classes, 13 object properties, five data properties and 34 individuals. The use cases for results and discussions have been inferred from the Poempuhar ontology.

Results and discussion

Here we discuss the use case to extract the related knowledge of the port city events caused in offshore and onshore sites using the Poempuhar ontology.

Offshore excavations – archaeological evidences

Digital Poempuhar evidence has been categorized under three variant sources: archaeological, geological and literary parts. The offshore excavation data of Poempuhar were extracted from archaeological evidence on ancient artefacts like pottery, jewellery made of beads and terracotta, copper objects like vessels, rings, bangles, wires and rattle, stone objects like

Table 4. Poempuhar property mapping with domain entities

Created entity	Object properties	Description
Linguistic object (E33)	Represents (P138)	Explored evidence found in the epics (<i>Pattinapalai</i>) is mapped with physical man-made things (E24) identified during archaeological excavation such as excavated burnt bricks
CIDOC CRM entity	Depicts (DPpro) Properties	To Map civilization and culture which explored in various languages
E33: Linguist object	P72: has language	Created classes property mapping
E90: Symbolic object	Has inscriptions	Evident inscriptions
E24: Physical man-made thing	P45: consists	Depicts civilization
		To excavate burnt bricks

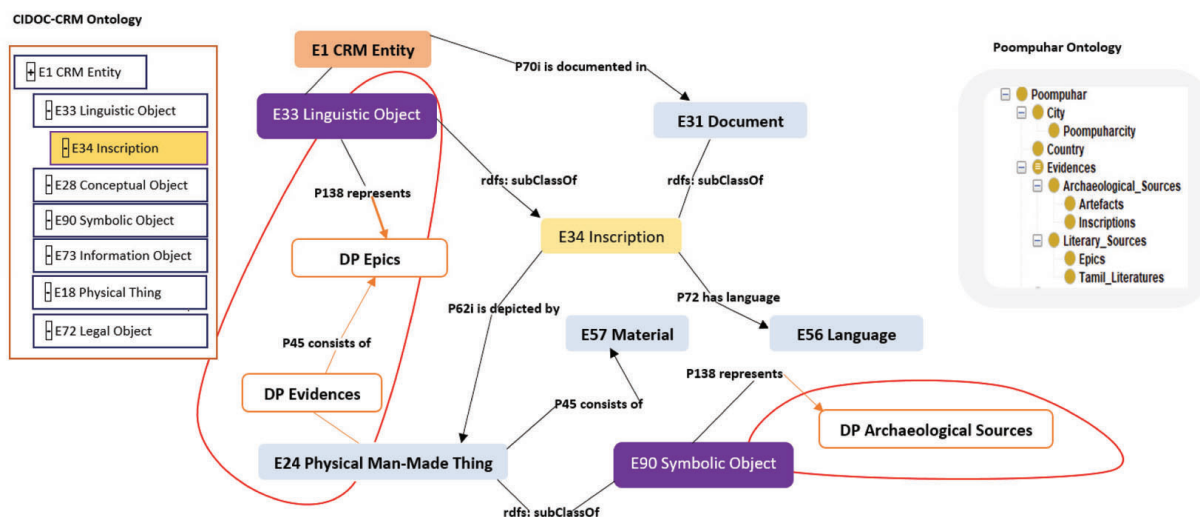


Figure 5. Indirect entity mapping (CIDOC CRM concept – digital Poempuhar ontology).

pestles for grinding grain, iron knives, nails, brick figures and copper coins. The objects identified through archaeological excavation described in the epics were integrated and related with geological locations mapped to districts in the Poempuhar ontology as the knowledge base.

Use case 1: Integrated information: archaeological evidence on Poempuhar excavation objects

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 the epics like *Ahananuru*, *Purananuru*, *Pattinapalai*, *Silappadikaram* and *Manimekalai* were integrated and mapped with offshore locations Kilaiyur, Vanagiri and Sampaththi Amman Temple¹. The Poempuhar ontology was also integrated with information extracted from the literature review of geological studies related to offshore excavation locations^{24,25}.

Knowledge mapping: Buddha statue: In 1927, near Melaiyur some offshore evidences of Poempuhar like gold-plated statues of Buddha or Bothi Sathuva Mytheya, Wharve

structures were identified¹. These evidences are mapped with timeline, period and spatio-temporal location concepts.

Use case 2: Integration of Sangam literature of Poempuhar evidence

The Sangam literature and epics elaborate the whole town-planning system of ancient Poempuhar^{22,25}. The glory of Poempuhar and the life and achievements of King Thirumavalavan, also known as Karikala Cholan, are also mentioned.

Mapping of history of rulers described in poetry: The Chola king Musunkunda Chakravarthy ruled from the city of Karur (present). His rule ended with the conquer of the fortress by the mythological Chola king Sembian²⁴.

Knowledge mapping on the exploration of the ancient town of Poempuhar with the epic Silapathigaram: The ancient town of Poempuhar was surrounded by five mandrams, four gardens, and nearly 16 temples as mentioned in the epic *Silapathigaram* listed with town layout containing avenues, streets, mansions, residences of foreign merchants, gardens, market places, traders, workshops, well-designed streets occupied by Yavana sailors, overseas traders, weavers, silk

Table 5. Poompuhar ontology property mapping

Properties	Type	Axioms
Property relations		
DP: found_yields DP: Cauvery delta	Transitive property Functional property	Yields (evidence) found in more than one place. Islocatedin connects a city to a single country (a city may not be located in two countries). River cauvery delta movement along with the changes of sea level contains explorations of submerged puhar ³ . DP: cauverydeltas owl: ObjectProperty Owl: inverseOf DP: ContainsExplorations
DP: nearby cities	Inverse property of DP: ContainsExplorations as a property chain	Connects a city to the neighbouring countries to establish trade links and culture-sharing. DP: found_yields a owl: ObjectProperty.
DP: Country DP: State and DP: City	Disjoint with	DP: Country owl: disjoint with DP: State, DP: City. DP: State owl: disjoint with DP: City.
Class axioms		
DP: Archaeological_Sources	Complement	Two complement subclass of DP: Archaeological_Sources: one for artefacts and another one for inscriptions, such that no member of one class can be a member of the other. DP: Artefacts rdfs: subclassof DP: Archaeological_Sources. DP: Inscriptions rdfs: subclassof DP: Archaeological_Sources; Owl: complementOf DP: Archaeological_Sources.
DP: Evidence	Union of	Literary sources (epics, Tamil literature) and archaeological sources (artefacts, inscriptions) can be described as evidence. DP: Evidences a owl: Class; owl:unionOf (DP: Archaeological_Sources DP: Literary_Sources).
Property value restriction		
DP: City DP: Country DP: locatedIn	Has value	The ancient port city located in Kaveripoompattinam, property value restriction depicts as DP: City and DP: locatedIn. DP: City a DP: locatedIn. DP: portcity a owl: Class; rdfs: subclassOf DP: City rdfs: subclassOf (a owl: Restriction; owl: onProperty DP: isLocatedIn; owl: hasValue DP: Kaveripoompattinam).

traders, grain merchants, jewellers and gem makers⁷. Figure 7 shows the domain mapping of Poompuhar temples, gardens and mandrams inferred from the literature as a knowledge graph.

Onshore explorations – geological evidences

The onshore exploration of Poompuhar below sea level based on scientific studies in the literature was integrated into the Poompuhar ontology.

Use case 3: Geological evidence for Poompuhar region through explored structures under the ocean

Mapping Poompuhar submergence onshore evidence with the literature: Poompuhar has submerged due to natural calamities like tsunami, floods, coastal erosions or sea incursions. In epics and literatures, information about the submergence of city can be found¹⁻³. Using past shoreline data

from general bathymetric chart of the oceans (GEBCO), traces about the existence of submerged Poompuhar with geographical evidences have been reported^{1,8}. The geographical onshore explorations revealed coast cairn circles, urn burials (Suryakundam, Somakundam, U-shaped structure) at a water depth of 8–25 m in the Bay of Bengal near the shoreline, sand sediments and the movement of shoreline data¹⁶. Presently, the Poompuhar location exists with six villages, namely Sayavanam/Thirusaikadu, Pallavanisvaram, Mellapperumpallam, Keelaperumpallam, Keeziyur and Vanagiri². The evidences on submergence of Poompuhar from literatures and onshore explorations are associated and related with Poompuhar Knowledge model.

Conclusion

In this study, an integrated data model has been developed using ontology for the ancient port city of Poompuhar by integrating heterogeneous data from archaeological, geological and literary evidence. The existing properties and

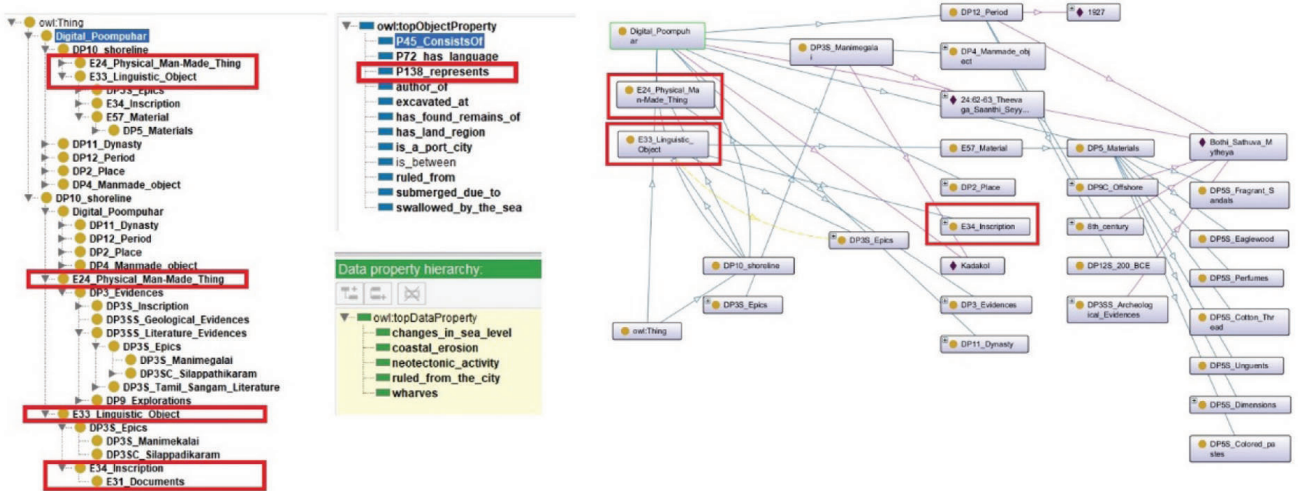


Figure 6. Poempuhar ontology.

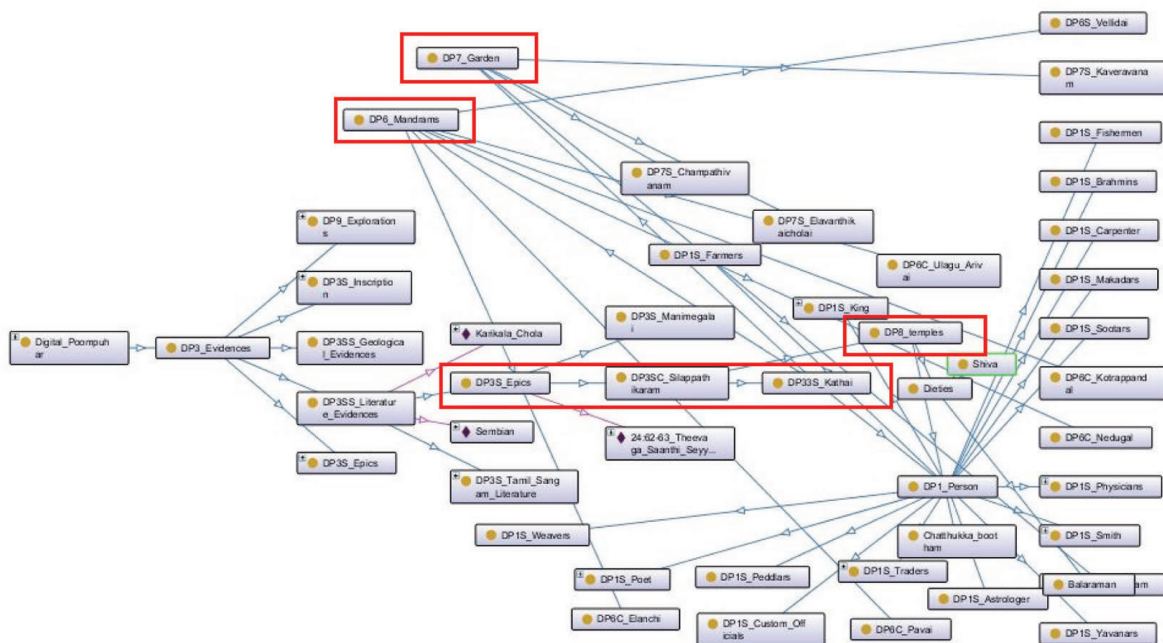


Figure 7. Knowledge inferred for Poempuhar town mapping with the literature.

classes of the cultural heritage knowledge model CIDOC CRM were reused with additional domain entities and properties to map the events of the submergence of Poempuhar. CIDOC CRM entities were mapped directly to relate events with evidence from the literature and archaeology. Indirect mapping was done to related events that occurred onshore using the new domain entities created. The experimental results were explored as knowledge graphs inferred from the knowledge base for various use cases related to the submerged Poempuhar excavated evidence. The excavation equipment and devices are not described in the mapping, which is a limitation and will be updated in the future version of the Poempuhar ontology.

Conflict of interest: The authors declare that there is no conflict of interest.

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