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Abstract. The inscribed text from the past on the stone represents an invaluable source for archaeologists and historians, who play a vital role in preserving and analyzing these inscriptions. Engraved on a durable material accompanying monuments, memorials, and statues or standing by their right, epigraphs are exposed to the same environmental and anthropogenic hazards threatening monuments. Their importance as historical and cultural objects is so well recognized that they retain a prestigious place among all ancient artifacts. They are the first to apply the latest technological breakthroughs for their documentation. This is evident from the application of the invention of photography to the modern use of artificial intelligence deep neural networks in textual restoration. Digitization of inscriptions represents the first step for their preservation, publishing, and dissemination among scholars and the public. However, the second step, their encoding, allows their computational analysis within the linked-data environment by generating machine-readable documents. Herein, we will describe the guidelines of the latest version of the Epigraphic Documents (EpiDoc) in Text Encoding Initiative (TEI) Extensible Markup Language (XML) (https://epidoc.stoa.org), a specialized edition for encoding of inscribed ancient text, which deals with the text and the historical context of the epigraph production. The Europeana network of Ancient Greek and Latin Epigraphy (EAGLE) (https://www.eagle-network.eu/), the Aphrodisias in Late Antiquity (InsAph) (https://insaph.kcl.ac.uk/ala2004/), the Atlas patrimonii Caesaris (https://patrimonium.huma-num.fr/documents/), and the Packard Humanities Institute (PHI) (https://epigraphy.packhum.org/) projects will be discussed in the context of the Greek Directorate for the Management of the National Archive of Monuments (https://www.arxaiologikoktimatologio.gov.gr/).

Keywords: Digital Humanities, Digital Epigraphy, EpiDoc, Conservation, Cultural heritage, Data management.

1 Introduction

The Mediterranean basin, the cradle of so many civilizations continuously inhabited from prehistory to modern times, is rich in ancient monuments, inscriptions, epigraphs, and texts. Assyrian tablets of the 21st to 16th century, Egyptian hieroglyphs of the 13th century, Linear B tablets of the same era, Akkadian scripts of the 5th century BC,

Classical Greek epigraphs of the 4th century BC, Hellenistic scripts of the 3rd century BC, Persian, Israel, Roman epigraphs of the 2nd century BC to 2nd century AD, Byzantine and Western Christianity, as well as Islamic and Ottoman monumental scripts apart the complex and fertile cultural mosaic of this geographic region [1]. The inscribed text on the stone is invaluable for archaeologists and historians. The written text represents the predominant evidence of historical documentation and understanding of the past.

The inscriptions and epigraphs are the authenticated primary sources necessary for historical restoration, authorship attribution, chronological context determination, geographical information, social and cultural conditions examination, and topic critical analysis without biases or groundless assumptions. In historiography, no description can be entirely neutral; history is fundamentally ambivalent; and the account of events is not just about individuals but of groups [2]. Inscriptions when accompanying monuments deliver to us different narratives, occasionally overlapping but non-exclusive: entertaining, memorializing, commemorating, glorifying, celebrating, legitimizing, justifying, explaining, offering instruction, providing administrative records, warning, criticizing, or just immortalizing the past, delivering the truth about it. An example of administrative recording represents the inscription of the Propylaea stele found in 1836 during the Acropolis of Athens excavations, which delivers the accounts that refer to the Erechtheion construction at the end of the 4th century BC (see Fig. 1).

Fig. 1. Details of the inscription from the Propylaea Stele documented the financial accounts for constructing the Erechtheion (408-407 BC, Acropolis of Athens Museum).

The importance of epigraphs as historical and cultural objects and the need for their preservation and documentation has been recognized since the beginning of modern archaeology, and the technological breakthroughs of each era have been applied to their recording. This is evident from the application of the invention of photography as early as it was discovered in the 19th century [3] to the modern use of artificial intelligence

deep neural networks in textual restoration when necessary [4]. Despite their durable nature, as most epigraphic inscriptions have been lettered upon hard substances, such as stone, bronze, or ceramic, they are subjected to decay, spoilage, and attrition, with a significant risk of destruction and perdition. Epigraphs are laid to the environment and exposed to physical and anthropogenic hazards, such as season changes, fires, earthquakes, floods, wars, vandalism, or excessive tourism that threaten the monuments. An example of the importance of documentation and recording of an ancient artifact with inscriptions represents the case of the blocking outer doorway of Tutankhamun's tomb, full of stamps and ancient Egyptian official seals, which Howard Carter and Lord Carnarvon partially dismantled to access the tomb during their 1922 excavation (see Fig. 2).

Fig. 2. On the left is a photograph of the outer doorway of Tutankhamun's tomb before any intervention, and on the right are Howard Carter and Lord Carnarvon, as they partially dismantled the doorway during the tomb's excavation in 1922.

It has been postulated that the deterioration of ancient monuments in our age has entered a crisis phase, as can be documented by the annual loss of ancient cultural heritage of such a magnitude that many of the monuments taken for granted today may not survive for the next generation [3]. Digital epigraphy offers the means to preserve this heritage, study, examine, translate, and analyze the content, and reconstruct the information from fragments or lacunae using computer technologies [4]. Photography, scanning, vector drawing, and optical character recognition (OCR) could accurately digitally represent an epigraph. At the same time, epigraphic documents (EpiDoc) in text encoding initiative (TEI) extensive markup language (XML) provides the framework for encoding epigraphic text, transcription, editorial treatment, material of the object, and attributes description [5].

2 Digital epigraphy

From the many significant transformations that epigraphy has experienced recently, incorporating digital technologies is the most disruptive and pervasive development. The digital transition of humanities calls for interdisciplinary action, developing new methodologies for artifact facsimile generation and analyzing information, storage, and management. The technological innovations concerning epigraphy are (a) the electronic textual representation and the delivery of information from analog to digital form by optical character recognition (OCR) methodologies; (b) the textual restoration, recovery of missing text, and reassembly of fragmented epigraphs; (c) the electronic delivery of context and attributes of the epigraph, including authorship, chronology, and geographic origin; (d) linguistic text parsing, part of speech tagging and segmentation; (e) philological textual criticism; and (f) translation and interpretation to facilitate modern readers demand [6].

Epigraphic inscriptions are 3D objects with text, context, and historical attributes. Deciphering epigraphic text and context through digitizing inscription facsimiles could be achieved through digital photography and electronic restoration by morphological residual modeling or through 3D scanning and contrast filtering. Vector drawing and on-site collation of the proofs, editing, and correcting would produce an accurate digital facsimile, based on algorithmic curves trace matching and not pixels, of the artifact for storage, studying, or publishing [7]. The context and attributes should accompany, as informational attachments, these electronic documents, thus providing an as complete as possible information scheme of the authorship, chronology, and geographic origin of the item [8].

An untrained linguistic analysis solution applicable to digital epigraphy could be derived from the semantic analysis of a set of terms, single words, or multi-word expressions derived from a body of texts and organized in a master index [9]. After converting multi-word expressions into single words, the index is processed dualistically as intact terms and, after their split, single words. The frequency of their appearances ranks the extracted terms or single words after duplicates are eliminated and analyzed by latent semantic analysis (LSA). The resulting index can be rebuilt after correlating external resources in the proposed paradigm to WordNet and relational analysis with the authorities and the subject headings of the Library of Congress (LCSH) and the National Library of Greece (NLG_SH). Thus, a machine-readable index is generated for further philological interpretational tasks, classified by cultural heritage criteria, searchable, and matching the original body of texts (see Fig. 3).

Digital epigraphy alleviates the pain of analyzing copious quantities of historical information from multiple resources by producing digital libraries that can be assessed online, applying social network and spatial analysis, enhancing epigraphic collaboration [6], and providing investigators with data that can be further analyzed by computational [9] or artificial intelligence technologies [10]. To these ends, text markup and encoding are of particular importance.

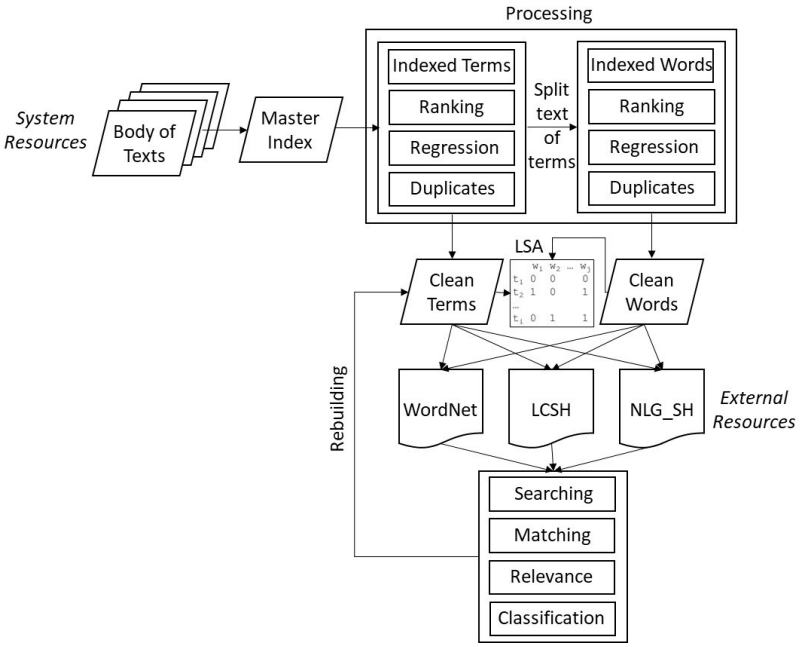

Fig. 3. Diagrammatic presentation of the building architecture of a terminology index from digital epigraphy corpora for philological interpretational tasks.

3 EpiDoc

The Epigraphic Documents (EpiDoc) standard is based upon the Text Encoding Initiative (TEI) standard, which is a form of Extensible Markup Language (XML). XML is a text markup language and a file format that, unlike HTML, has no predefined tags for encoding documents in a human- and machine-readable form, reconstructing data, storing, searching, sharing, and transmitting across different systems and platforms. This open and highly flexible, user-defined standard attracted the interest of the TEI community, which develops and maintains standards for the representation of texts in digital form. TEI issues guidelines that define the tags that contain text (opening and closing markup delimiters) as specific documentation elements, attributes, values, classes, modules, models, and datatypes [11]. In TEI syntax and XML, an element may be a child element to a parent one. TEI is an interdisciplinary standard of mostly text-based physical artifact description that serves the needs of various cultural heritage institutions (such as libraries, museums, publishers, and researchers) to represent the literature body of texts. Any sort of work or artifact can be described with TEI markup. This hierarchically structured formation significantly increases the markup language's descriptive capacity to include text, context, properties, authorship, spatial and temporal information, edition details, and copy details, including notes and attritions of the

specific copy encoding. In TEI XML, tagged elements are nested, represented, and hierarchically structured. For example, for the representation of a poem in an anthology, the start and end tags are defined as an anthology; within the anthology, there is the poem, its title marked with a heading tag, and then its stanza, separately represented one by one. Within its stanza is a description of each line of the poem. The structured nested description allows the citing of specific elements encoding in the XML file. TEI guidelines detail every element, tag, class, or macro to describe any sort of work or artifact and its dimensions, notes, and attritions in the object. The development and maintenance of a highly expressive and descriptive standard format to encode text allow the delivery of different modules of hand-written or published works, such as analyses and interpretations, metadata for language corpora, print dictionaries, performance texts (drama), tables, formulae and figures, special characters and glyphs, names, dates, people and places, graphs, networks, and trees, transcribed speech (spoken), text criticism, text structure, transcriptions of primary sources, or verses, that could be applied in digital humanities.

Like the TEI community, the EpiDoc international consortium dedicates its coordinated efforts to produce guidelines for encoding in-depth epigraphic text in digital human- and machine-readable format [5]. Initially developed in 2000 for Greek and Latin epigraphy (such as Inscriptions of Aphrodisias [12] and Vindolanda Tablets [13]), EpiDoc was expanded to include the publication of papyri and manuscripts [14] and adapted to encode other script traditions such as Egyptology, Coptic, Hindu, Maya, Mycenaean, pre-Islamic Arabian, multi-language texts, abbreviations, monograms and symbols [6]. Since CIDOC-CRM (Conceptual Reference Model), the ontology standard developed by the International Council of Museums (ICOM), is used to define the ontological layer of cultural objects, including textual entities such as epigraphs, epigraphers apply both EpiDoc and CIDOC-CRM to document epigraphs [6]. In parallel, the Europeana network of Ancient Greek and Latin Epigraphy (EAGLE) is trying to combine these two systems to deliver the text accompanied by the standardized representation of the physical aspects of an epigraph together with its context [8]. In addition, considering the broader definition of epigraphy, EpiDoc can also be used in sigillography and numismatics.

Herein, we will describe the guidelines of the latest version of the Epigraphic Documents (EpiDoc) in Text Encoding Initiative (TEI) Extensible Markup Language (XML) (https://epidoc.stoa.org), a specialized edition for encoding of inscribed ancient text, which deals with the text and the historical context of the epigraph production. EpiDoc guidelines specify a subset of the TEI standard for representing ancient epigraphic documents in digital form through XML. The annotated phenomena are linguistic (onomastic, grammatical), philological (lacunae, restorations, corrections, etc.), and descriptive of the relation between text and support (line breaks, text turning around the object) or of the internal structure of the text (genealogies, eponyms). Specialized communities of contributors focus on Greek, Latin, Egyptology, Coptic, Hindu or Mycenaean text transcriptions. EpiDoc Guidelines aim to align information according to conventions for epigraphic transcription and metadata standards. EpiDoc monumental inscription representation combines the text with the historical context of the epigraph production.

The descriptive and representation functionalities of EpiDoc are supported by sets of elements required for transcription, supporting information, and vocabulary and indexing. EpiDoc uses the same elements as TEI in most cases, but their definition is customized for EpiDoc descriptive tasks [15]. For text transcription, there are elements define (a) the structure of the text, its direction, verse lines, the manner of word divided across lines, metrical elements, and paragraphs; (b) the text per se, its clarity, cases of uninterpreted, ambiguous, damaged or erased characters, ancient corrections, illegible characters, lost characters or lines, lacuna, spaces that never contained text (vacat), changes in scribe or hand, and text not completed; (c) its form and appearance, including highlighted characters, special characters, raised or lowered, tall or small characters, reversed or inverted letters, symbols, and monograms; (d) editorial interventions, such as restored text, uncertainly text, correction, abbreviation, expansion, foreign text, and editorial note; and (e) interpretation, numeral, fraction, acrophonic and quotation marks. Another set of elements is necessary to describe images accompanying text-bearing objects following the TEI Gudelines to represent primary sources. For the vocabulary and indexing, elements such as contents, summary, keywords, and terms can be used, together with tagging of lexical words and lemmatization, personal names, prosopographical links, place names, and geographical terms mentioned in the text, titles, offices and occupations, military, religious and socio-economic terminology, events, dates, and month names. For the alignment of object, text, and context description with controlled vocabularies and authority lists outside the TEI environment, EpiDoc allows references into the element (@ref) that point to the external vocabularies. These references may point to EAGLE Type of Inscription Vocabulary [16], EAGLE Object Type Vocabulary (including monuments) [16], Getty Museum (Art & Architecture Thesaurus® Online) [17], EAGLE Engraving Technique Vocabulary [16], EAGLE Material Vocabulary [16], Salzburg Simplified Petrography [18], EAGLE Dating Criteria Vocabulary[16], date of origin PeriodO [19], EAGLE State of Preservation vocabulary [16] or EAGLE Decoration vocabulary [16]. Through these reference links, the expressiveness of EpiDoc is enhanced to describe epigraphs and monumental inscriptions in explicit detail.

4 Collections of EpiDoc Encoded Inscriptions

The pioneer EpiDoc project that greatly assisted the development of its protocols, guidelines, and tools was the *Inscriptions of Aphordisias*, an archaeologic site in Caria, southwest Turkey, with an ancient Hellenistic and Roman historical background, considerably rich in inscriptions of excellent quality [12]. Most of these inscriptions are from the late Roman period, second or the early third centuries AD. Formal inscriptions, fragmented or intact, public inscriptions, honoring rulers or benefactors, recording decrees, or dedicating buildings, as well as funerary, gameboard, place inscriptions, prayers and invocations, and verses, represent some of the different categories of text found there, located on columns, masonry blocks, panels, plaques, statue bases, most of them inscribed on marble. The inscriptions' text and context can be assessed directly from

the website by number section, findspot, date, text category, or monument type, and downloaded as the inscription in EpiDoc XML format.

The *Europeana network of Ancient Greek and Latin Epigraphy* (EAGLE) is another source of EpiDoc encoded inscriptions by various contributors [16]. This website offers basic and advanced search and image search to retrieve text, images, or artifacts related to the query. Also, there are filters to select for decoration, material, object type, state of preservation, type of inscription, writing, ancient find spot, modern find spot, has image, has translation, and content provider.

Another database of EpiDoc encoded inscriptions is the PATRIMONIVM project *Atlas patrimonii Caesaris (APC)*, where a collection of nearly 5000 documents with geographic information, age, references, and details is stored [20]. The aim of the project is the research of imperial properties at the scale of the entire Roman empire. The website allows direct search and filter search by document, people, places, geographic area (map), or keywords. The geographic areas covered include Africa, Alpine provinces, Asia Minor, Balkan provinces, Britain, Crete-Cyrene, Cyprus, Egypt, Gaul and Germany, Greece, the Iberian Peninsula, Italy, Sicily, Sardinia, Corsica, and the East. The keywords of APC's thesaurus cover civic life, economy, geography, prosopography, religion, Roman administration, Roman law, and society. The references of the inscriptions of Atlas patrimonii Caesaris are stored in Zotero.

EpiDoc-encoded searchable Greek inscriptions are available from *The Packard Humanities Institute (PHI), PHI Epigraphy Project* [21]. The content can be searched directly, or the inscriptions can be browsed with the assistance of a geographic locator. The geographic locator covers Attica, Peloponnesos, Central Greece, Northern Greece, Thrace and the Lower Danube, North Shore of the Black Sea, Aegean Islands including Crete, Asia Minor, Cyprus, Greater Syria and the East, Egypt, Nubia and Cyrenaica, North Africa, Sicily, Italy, and the West, Upper Danube, and Unknown Provenances.

The Greek National Archive of Monuments recently introduced the *Arcaehological Cadastre*, an interactive map of natural and archeological monuments, museums, and sites. The website offers navigation to these places within the limits of the Greek district [22]. Although this project is not directly associated with the EpiDoc, it facilitates the geographic location of an archaeological site of interest.

The ITHACA project is another interesting tool for restoring information on fragmented textual data [4]. ITHACA may also attribute ancient texts using deep neural networks and assist in identifying the geographical and chronological of ancient Greek inscriptions [23]. The geographical localization examines eighty-four regions of the ancient world, and the chronological attribution searched a period between 800 BC and 800 AD.

5 Discussion

Epigraphy is a discipline of research with a history exceeding one thousand years. Scholars' interest in the inscriptions of the past, historical information, and philosophical considerations delivered, hoarded in transcriptions and anthologies, have entered the 21st century into the digital era [24]. Digitization of cultural objects, documentation,

recognition of information, quality enhancement, optical character recognition, bridge the physical textual sources to the electronic reconstructed facsimile. From the library and information science (LIS) perspective, the question is how to convey this raw data by encoding them in an organized, storable, searchable, retrievable, and transferable machine-readable mode to deliver them for the consumption of end users within the semantic web linked-data computational environment.

EpiDoc, a metalanguage developed by epigraphers for epigraphic, philological, and historical use, is the markup language that delivers text and context in a human- and machine-readable format. Utilizing the XML flexibility of structured and semantic markup and the TEI guidelines for defining elements and attributes to describe written or published text, EpiDoc sets a matched equivalent between Leiden codes of epigraphy and markup features for the electronic encoding to form its guidelines [24]. The attribution of authorship, spatial and chronological information, palaeographic information, and the topic of the text can also be delivered in the same file as the text. In addition, information on the investigator who first described the object, the era of discovery, and relative bibliographic citations could be included. The EpiDoc file describes the object's physical condition and possible uncertainties, lacuna, vacat, special condition of the inscribed characters and appearance, and editorial interventions, such as restored text or corrections. On top of this, EpiDoc allows references to external control vocabularies outside the TEI environment, which increases its expressiveness and descriptive capabilities of cultural fragments, items, objects, and monuments. Ultimately, the EpiDoc file delivers a complete electronic reconstruction of the described object together with background and bibliography.

EpiDoc-encoded files, despite their role in historical documentation, facilitate linguistic investigators' analysis, semantics, part-of-speech (POS) tagging, text parsing, and segmentation, as well as philological textual criticism, style, intertextual relationships, and stemmatology. Importantly, EpiDoc encoding makes possible automatic computational approaches, including artificial intelligence applications for textual restoration, as in the case of the ITHACA project [23], and fragment reassembly or automatic translation to modern-day languages, which assist comprehension and interpretation by contemporary researchers. As we proposed herein, EpiDoc files could be used for the textual organization and analysis of collections of texts, including inscriptions of geographic regions and historical eras, by performing latent semantic analysis and index rebuilding with WordNet for English-translated content and relational analysis with the authorities and the subject headings of the Library of Congress and the National Library of Greece. This approach may produce organized text corpora linked to cultural heritage information with improved search and retrieve capabilities. It should be noted that this approach may serve as a platform for cross-cultural heritage unification studies.

6 Conclusion

In conclusion, encoding of epigraphic documents and monumental inscriptions with the EpiDoc standard ensures (a) a universal standard for information delivery, (b) the

preservation of ancient information, (c) the compatibility with html publishing, (d) the data transfer and dissemination, (e) the interoperability between different platforms, (f) the accessibility by scholars and the public, as well as (g) applying automatic computational solutions including artificial intelligence systems for organization, indexing, textual restoring and attributing parameters options.

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