Context and Georeferencing of Archaeological, Prehistorical, and Geoscientific Object Entities, Resulting from Integration of Knowledge Resources' Development and Universal Conceptual Knowledge Pattern Matching

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Abstract—**This paper presents the long-term research results on context creation and georeferencing, deploying advanced knowledge based mining, enabled by conceptual knowledge frameworks. The goal of this fundamental research is to systematically develop advanced information science tools and knowledge-based methods, gaining new insights for complex archaeological, prehistorical, and geoscientific contexts. The vast resources and data collections are otherwise not practically available to archaeologists and geoscientists. The paper presents the methodological base of an innovative algorithm framework of conceptual knowledge pattern matching, allowing the consideration of complementary and descriptive knowledge of meaning and intrinsic object properties. The research is illustrated by practical implementations of knowledge pattern matching, including processing and developing multi-disciplinary and multi-lingual knowledge object entities and resources. This specialised research concentrates on geoscientific context and georeferencing. The demonstration of a previously unpublished practical information science case study from classical archaeology, prehistory, and geosciences shows automated knowledge context creation and georeferencing.**

Keywords*–*Knowledge Context Creation; Georeferencing; Archaeology and Geosciences; Superordinate Knowledge; Conceptual Knowledge Pattern Matching Methodology.

I. Introduction

Advanced creation of context and georeferencing from multi-disciplinary archaeological, prehistorical, and geoscientific object entities is a most challenging task. So far, there is no consistent, practical concept available relieving the fundamental deficits of respective resources, especially motivating new fundamental ways of concepts' integration.

This extended research is based on the creation of advanced knowledge resources and implementation of the Conceptual Knowledge Pattern Matching (CKPM), which was presented at the GEOProcessing 2020 conference in Valencia, Spain [1].

This paper presents developments, which are complementary to conceptual knowledge deployed in knowledge resources and processing method used so far. The new developments closely integrate with features enabled by knowledge-centric development of resources and objects. The presented cases focus on basic phonetic associations and topographic and cartographic context creation and visualisation, starting with advanced knowledge mining.

Knowledge Mining is supported by a number of common methods and algorithms, e.g., string pattern matching algorithms, associative, comparative, and phonetic algorithms. All these achievements deal with distinct extrinsic properties of respective entities in very limited ways.

The motivation for creating the CKPM was the lack of suitable facilities for an advanced matching of 'meaning' when implementing mining solutions in context of complex multi-disciplinary and multi-lingual Knowledge Resources. Especially, conceptual knowledge can relate to any of factual, conceptual, and procedural knowledge. To a comparable extent, metacognitive knowledge can also relate to any of factual, conceptual, and procedural knowledge but the formalisation of conceptual knowledge is different in a way that universal implementations can be deployed in flexible and still consistent ways. A practical approach for knowledge pattern matching is the fundament for this research. Its methodological fundaments and the practical integration with the development of universal knowledge resources will be presented in the following sections, targetting on the practical creation of object entities' context and georeferencing.

The rest of this paper is organised as follows. Section II provides the background of knowledge complements and formalisation of meaning. Section III introduces the previous work and components. Sections IV presents methodology, method, and implementation. Sections V, VI, and VII present the implementation, matching process, and resulting tables. Section VIII provides an implementation of module integration for the result of context creation and georeferencing. Sections IX and X discuss the main achievements and summarise conclusions and future work.

II. From meaning and structures to knowledge complements

Knowledge, meaning, and patterns form relations, which may require some introduction.

The concept of meaning differs from the concept of signification. Semantic and syntactic structures do not suffice to determine the discursive meaning of an expression [2]. Discourse means a way of speaking. On the one hand, grammatically correct phrases may lack discursive meaning. On the other hand, grammatically incorrect sentences may be discursively meaningful.

Such formalised approaches require a solid understanding of interpretation [3] and application of methods. Fundamental approaches, especially, the semiotic triangle of symbol, thought/Reference, and referent [4] are fundamental for understanding principles.

Knowledge and meaning are closely tied with intrinsic and extrinsic properties. Therefore, understanding of intrinsic and extrinsic properties of entities is significant for any context.

This is nevertheless true for any case of natural language, esp. considering langage, langue, and parole [5].

Creating practical approaches requires algorithms. An algorithm is a process or set of rules to be followed in problem-solving operations. In general, algorithms cannot, by their fundamental nature, handle intrinsic and extrinsic properties to the same quality and extent. For example, an intrinsic property of a word object is the meaning in mind, the 'lemma'. An extrinsic property of a word object can be a written word. Extrinsic properties do not reflect meaning and insight as their representations do not generally allow reasonable results. Best practice provides us with solid, complementary knowledge concepts and methodologies allowing to create advanced methods.

Data do not have or carry meaning. Therefore, understanding meaning is of major significance in information science when dealing with improving formalisation processes and creating 'logos based' analogies along with cognitive processes. Commonly, cognition (cognitio, from Latin cognoscere, "get to know") is the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses (Source: Oxford dictionary). Analogy (from Greek analogia, ἀναλογία, "proportion") is a cognitive process of transferring information or 'meaning' from a particular subject, the analogue or source, to another, the target.

Nevertheless, aspects of meaning can be described using knowledge complements, e.g., considering factual, conceptual, procedural, and metacognitive knowledge [6]. Especially, conceptual knowledge can relate to any of factual, conceptual, and procedural knowledge. To a comparable extent, metacognitive knowledge can relate to any of factual, conceptual, and procedural knowledge. A practical approach for knowledge pattern matching will be presented in the following sections.

III. Previous work, components, and resources

The fundaments of terminology and understanding knowledge are layed out by Aristotle being an essential part of 'Ethics' [7]. Information sciences can very much benefit from Aristotle's fundaments and a knowledge-centric approach [6] but for building holistic and sustainable solutions, supporting a modern definition of knowledge [8], they need to go beyond the available technology-based approaches and hypothesis [9] as analysed in Platon's Phaidon.

Making a distinction and creating interfaces between methods and the implementation applications, the results of this research are illustrated here along with the practical example of the Knowledge Mapping methodology [10] enabling the creation of new object and entity context environments, e.g., implementing methods for knowledge mining context.

The means to achieve such recommendations even for complex scenarios is to use the principles of Superordinate Knowledge, integrating arbitrary knowledge. The core assembly elements of Superordinate Knowledge [11] are:

- Methodology.
- Implementation.
- Realisation.

Separation and integration of assemblies have proven beneficial for building solutions with different disciplines and different levels of expertise. Comprehensive focussed subsets of conceptual knowledge can also provide excellent modular and standardised complements for information systems component implementations, e.g., for environmental information management and computation [12].

For the implementation of case studies, the modules are built by support of a number of major components and resources, which can be used for a wide range of applications, e.g., creation of resources and extraction of entities. The Universal Decimal Classification (UDC) [13] is the world's foremost document indexing language in the form of a multi-lingual classification scheme covering all fields of knowledge and constitutes a sophisticated indexing and retrieval tool. The UDC is designed for subject description and indexing of content of information resources irrespective of the carrier, form, format, and language. UDC is an analytico-synthetic and facetted classification. It uses a knowledge presentation based on disciplines, with synthetic features. UDC schedules are organised as a coherent system of knowledge with associative relationships and references between concepts and related fields. The UDC allows an efficient and effective processing of knowledge data and provides facilities to obtain a universal and systematical view on classified objects. UDC-based references in this publication are taken from the multi-lingual UDC summary [13] released by the UDC Consortium [14] under a Creative Commons license [15]. Facets can be created with any auxiliary tables, e.g., auxiliaries of place and space, time, language, and form as well as general characteristics, e.g., properties, materials, relations, processes, and operations, persons and personal characteristics. Module examples are employing Perl Compatible Regular Expressions (PCRE) [16] syntax for specifying common string patterns and Perl [17] for component wrapping purposes with this information science case study in archaeology, prehistory, and geosciences.

In addition, context data, visualisation modules, and phonetic modules were developed and integrated for benefit of this research. The used components will be referred to in the respective following sections.

IV. Methodology and implementation

The implementation strictly follows the fundamental methodological algorithm base.

A. Methodological algorithm base

The Conceptual Knowledge Pattern Matching (CKPM) methodology targets providing and accessing knowledge object patterns. This methodological algorithm framework is based on the Superordinate Knowledge Methodology, which allows systematical use and thorough processing by the steps:

1) Selecting knowledge objects.
2) Accessing knowledge object patterns.
3) Thorough processing of object entities and references.
4) Object entity analysis, knowledge complements' based.
5) Result formation.

The respective accessing includes the organisation and structures used with the objects and entities. Object patterns need to be accessible to an extent and quality, which allows a sufficient processing for the respective scenario. The requirements for specific scenarios will therefore be individual. The processing includes making use of the characteristics and features of the respective implementations of the knowledge based frameworks providing a conceptual base for a certain method. The conceptual knowledge complements referred from knowledge objects can have their origins from manual as well as from automated processes. For the implementation and realisation, the framework providing the base conceptual knowledge reference patterns is the UDC. The results in this publication use the UDC Summary Linked Data (Main Tables, [18]). Creating facets and patterns can also make use of the common auxiliary signs being part of the UDC framework [19]. The following advanced employment of conceptual knowledge (UDC) is far beyond common application of universal classification.

B. Implemented method

An implementation of a CKPM based method requires accessible objects and a suitable conceptual framework base for processing and automation. The methodic implementation illustrated here enables to employ an UDC framework appropriate for systematical use, implemented by the steps:

1) Knowledge Resources' objects.
2) Accessing formalised conceptual knowledge object pattern description based on UDC, e.g., including geoscientific context and georeferencing.
3) Processing procedure via pipelines, employing UDC knowledge and forks.
4) Entity analysis, based on UDC framework references.
5) Result formation on base of Knowledge Resources' objects, retaining conceptual knowledge.

In this case, meaning is described by conceptual patterns, which can be searched and analysed. Processing algorithms can follow the given organisation, e.g., the decimal organisation of the UDC, following available forks as will be illustrated for the matching process in the following sections. Processing and analysis includes primary, decimal conceptual knowledge and associated multi-dimensional knowledge in context of the object entities. The method allows advanced data-centric computing procedures. In practice, the facility for consistently describing knowledge is a valuable quality, esp., conceptual knowledge, e.g., using the UDC and its editions.

C. Implemented conceptual knowledge framework and target

Targeting practical use for advanced geoscientific information and expert systems, conceptual geoscientific and geographic mapping and referencing are required. Geographic conceptual knowledge pattern entities are created based on UDC code references [20] of geography, biography, history. Table I shows an implementation excerpt.

TABLE I. CONCEPTUAL KNOWLEDGE PATTERN MATCHING: IMPL. UDC REFERENCES OF GEOGRAPHY, BIOGRAPHY, HISTORY (EXCERPT).

Code / Sign Ref.	*Verbal Description (EN)*
UDC:902	Archaeology
UDC:903	Prehistory. Prehistoric remains, artefacts, antiquities
UDC:904	Cultural remains of historical times
UDC:908	Area studies. Study of a locality
UDC:91	Geography. Exploration of the Earth and of individual countries. Travel. Regional geography
UDC:912	Nonliterary, nontextual representations of a region
UDC:92	Biographical studies. Genealogy. Heraldry. Flags
UDC:93/94	History
UDC:94	General history

A geoscientific / archaeology example from the case studies and implementations for geoscientific information systems and application components is used for illustration in the next sections. The example will show a tiny subset of the comprehensive, universal conceptual knowledge used.

The above conceptual knowledge contains all the references for geographic context, which includes the conceptual knowledge regarding geographic data, e.g., geoinformation and geodescriptive knowledge. The relevant conceptual knowledge required for geoscientific context is provided by references from natural sciences' context. Any of the conceptual knowledge can be used in any stage of a CKPM process, e.g., in start, intermediate, and target specifications.

Natural sciences related conceptual knowledge pattern entities are created based on UDC code references [21] of mathematics and natural sciences. An excerpt of the implementation is shown in Table II.

TABLE II. CONCEPTUAL KNOWLEDGE PATTERN MATCHING: IMPL. UDC REFERENCES OF MATHEMATICS AND NATURAL SCIENCES (EXCERPT).

Code / Sign Ref.	*Verbal Description (EN)*
UDC:51	Mathematics
UDC:52	Astronomy. Astrophysics. Space research. Geodesy
UDC:53	Physics
UDC:54	Chemistry. Crystallography. Mineralogy
UDC:55	Earth Sciences. Geological sciences
UDC:550.3	Geophysics
UDC:551	General geology. Meteorology. Climatology. Historical geology. Stratigraphy. Palaeogeography
UDC:551.21	Vulcanicity. Vulcanism. Volcanoes. Eruptive phenomena. Eruptions
UDC:551.7	Historical geology. Stratigraphy. Palaeogeography
UDC:551.8	Palaeogeography
UDC:551.24	Geotectonics
UDC:56	Palaeontology
UDC:57	Biological sciences in general
UDC:58	Botany
UDC:59	Zoology

Time related conceptual knowledge pattern entities are created based on UDC code references [22], especially the auxiliaries of time). Table III shows an implementation excerpt.

TABLE III. CONCEPTUAL KNOWLEDGE PATTERN MATCHING: IMPLEMENTED UDC REFERENCES, AUXILIARIES OF TIME (EXCERPT).

Code / Sign Ref.	*Verbal Description (EN)*
UDC:“0”	First millennium CE
UDC:“1”	Second millennium CE
UDC:“2”	Third millennium CE
UDC:“3/7”	Time divisions other than dates in Christian (Gregorian) reckoning
UDC:“3”	Conventional time divisions and subdivisions: numbered, named, etc.
UDC:“4”	Duration. Time-span. Period. Term. Ages and age-groups
UDC:“5”	Periodicity. Frequency. Recurrence at specified intervals.
UDC:“6”	Geological, archaeological and cultural time divisions
UDC:“61/62”	Geological time division
UDC:“63”	Archaeological, prehistoric, protohistoric periods and ages
UDC:“7”	Phenomena in time. Phenomenology of time

Spatial conceptual knowledge pattern entities are created based on UDC code references [23], especially the auxiliaries of spatial features and place (UDC (1/9)), (Table IV).

TABLE IV. CONCEPTUAL KNOWLEDGE PATTERN MATCHING: IMPL. UDC REFERENCES, AUXILIARIES OF SPATIAL FEATURES AND PLACE (EXCERPT).

Code / Sign Ref.	*Verbal Description (EN)*
UDC:(1)	Place and space in general. Localization. Orientation
UDC:(2)	Physiographic designation
UDC:(3)	Places of the ancient and mediaeval world
UDC:(31)	Ancient China and Japan
UDC:(32)	Ancient Egypt
UDC:(33)	Ancient Roman Province of Judaea. The Holy Land. Region of the Israelites
UDC:(34)	Ancient India
UDC:(35)	Medo-Persia
UDC:(36)	Regions of the so-called barbarians
UDC:(37)	Italia. Ancient Rome and Italy
UDC:(38)	Ancient Greece
UDC:(399)	Other regions. Ancient geographical divisions other than those of classical antiquity
UDC:(4)	Europe
UDC:(5)	Asia
UDC:(6)	Africa
UDC:(7)	North and Central America
UDC:(8)	South America
UDC:(9)	States and regions of the South Pacific and Australia. Arctic. Antarctic

Knowledge Resources' objects carry respective conceptual UDC facets and references, including georeferences.

V. BASIC PRINCIPLE PROCESSING IMPLEMENTATION

Regarding an implementation ('`lxgrep`'), a basic routine preparing object entity input into a common structure is illustrated in Figure 1.

```
if (/^(\S)(.*)/./^                /||/^$/||/^ *$/) {
  s/^(\S.*)\n/\@ENTRY\@$1@@/;
  s/^(.*)\n/\1@@/;
  s/\@ENTRY\@/\n/;
  open(TMPFILE,">>$tempfile"); print TMPFILE "$_"; close(
   TMPFILE);
}
```

Figure 1. Basic routine preparing input entries (excerpt).

An associated elementary system call implementing a basic regular search is shown in Figure 2.

```
system("egrep␣-h␣$temppat␣$ARGV[0].tmp␣>␣$ARGV[0].grep.
 tmp");
system("mv␣$ARGV[0].grep.tmp␣$ARGV[0].tmp");
```

Figure 2. Elementary system call for a basic regular search (excerpt).

An element for a simple system sort based function used with the above search is shown in Figure 3.

```
print "\tsorting␣entries...\n";
system("sort␣-f␣-k␣1,14␣<$tempfile>$tempfile.out");
unlink $tempfile;
```

Figure 3. Element of simple system call sort function (excerpt).

A simple backformatting routine is given in Figure 4.

```
print "\tbackformatting␣entries...\n";
system("perl␣-e␣'while␣(<>){s/@@/\n/g;chop;print␣$_}'␣<
 $ARGV[0].tmp>$ARGV[0].sort");
unlink "$ARGV[0].tmp";
```

Figure 4. Simple backformatting routine (excerpt).

For further structural, technical details, and pipelining please see the references for the case studies given in the text.

VI. NEW MATCHING PROCESS AND PROCESSING

The new framework of the matching process and processing includes following the conceptual knowledge forks. Here, the primary, decimal reference forks of the UDC are used for implementation, which provide the red line forks within universal knowledge. Matching is beyond non-conceptual knowledge, e.g., natural language processing and string pattern matching. Especially, country and border concepts cannot be used for specification, e.g., ancient and modern border lines fail to be useful. The process enables places in ancient Greece and Rome, from archaeological and prehistoric times associated with places in the ancient and modern world to be described, e.g., references of the type `UDC:..."63"(37)` and `UDC:..."63"(38)`. Trigger question can be 'Can archaeological artefacts' objects of a certain context be associated with earth science objects?'. A symbolic writing specifying a conceptual expression is shown in Figure 5.

```
STRT:[UDC:.*?90]
CTXT:[[UDC:.*?\(.*?38.*?\)]|[UDC:.*?\"6.*?\"]].*[[UDC
 :.*?\"6.*?\"]|[UDC:.*?\(.*?38.*?\)]]
SRCH:[[UDC:.*?55]|[UDC:.*?912]]
```

Figure 5. Example for symbolic writing of pattern expression (excerpt).

A systematic concept of conceptual knowledge implementation allows advanced features, e.g., pattern range variations, pattern permutations. A basic serial pipeline implementation example test for knowledge objects in `<input>` is shown in Figure 6.

```
cat <input> | lxgrep "'%%IML:.*?UDC:.*?\(38.*?\)'" |
 lxgrep "'%%IML:.*?UDC:.*?\"6.*?\"'" <outputctxt>
cat <outputctxt> | lxgrep "'%%IML:.*?UDC:.*?90'"
cat <outputctxt> | lxgrep "'%%IML:.*?UDC:.*?55'" | lxgrep
  "'%%IML:.*?UDC:.*?912'" | lxgrep LATLON:
```

Figure 6. Example for serial pipeline implementation (excerpt).

The pipeline includes objects containing and referring to latitude / longitude objects. The trackable spatial/place related fork process within the conceptual pattern entity group is illustrated in Figure 7.

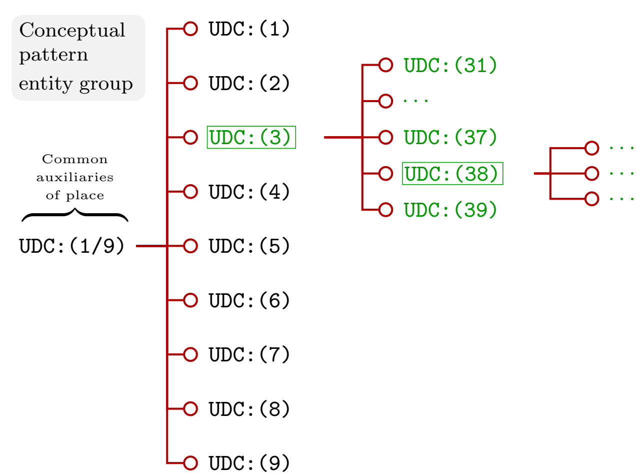

Figure 7. Matching process: Primary, decimal (UDC) conceptual knowledge forks, auxiliaries of spatial features and place (excerpt).

The processing successfully follows the "Ancient Greece" fork. Figure 8 illustrates the fork process within the conceptual pattern entity group for the related conceptual knowledge regarding time.

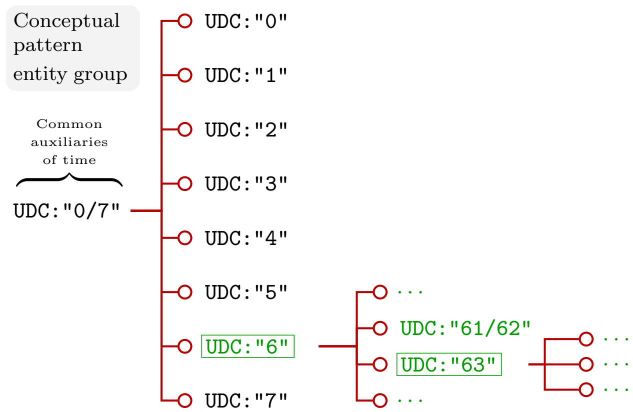

Figure 8. Matching process: Primary, decimal (UDC) conceptual knowledge forks, auxiliaries of time (excerpt).

The processing successfully follows the "geographical/historical" and "natural sciences" fork. The main tables of the conceptual knowledge are managed in the same way within the respective conceptual pattern entity groups (Figure 9).

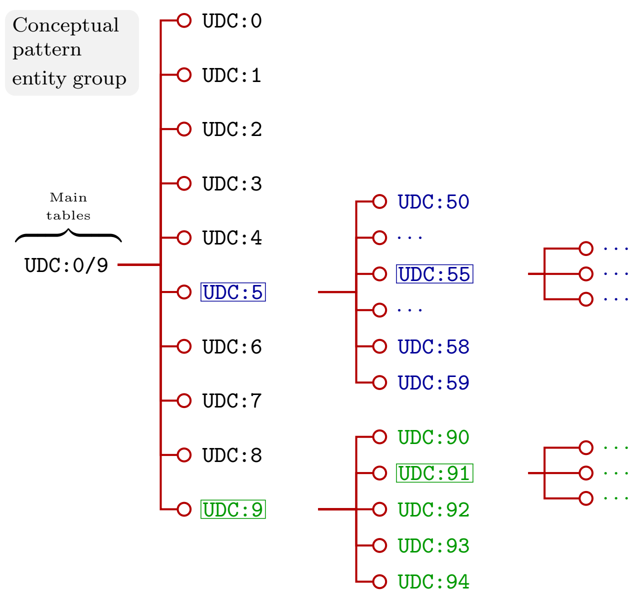

Figure 9. Matching process: Primary, decimal (UDC) conceptual knowledge forks, main tables, including earth sciences and geography (excerpt).

The processing successfully follows the "Earth sciences" and "Geography" forks. These procedures referencing to a formalised [24], practical framework of conceptual knowledge embrace all the relevant universal knowledge, e.g., including natural sciences and geosciences, archaeology, philosophy, and history. The results of removing in the domain of knowledge and removing in the domain of mathematics are not the same. In principle, abstraction means removing [25]. In the mathematical domain, removing is mostly formalised by subtraction [26].

In general, any universal conceptual knowledge framework can be used, which enables a systematical processing and which is universal and consistent. Nevertheless, UDC has proven to be by far the most universal, practical, and efficient choice for multi-disciplinary and multi-lingual context. Therefore, UDC references are used for this publication, illustration, and the practical implementations for this research.

Demonstrated meaning patterns can be used plain, e.g., on conceptual fundament, or integrating references between objects containing non-conceptual knowledge, too. The development target will certainly depend on intended case scenarios and capacities of resources' and module developers. This research can only demonstrate some principle, major features of UDC in context of an implementation done for the given practical scenario. However, it is always possible to parametrise conceptual knowledge depth and width of matches for any case due to the structure of the UDC implementation.

VII. Resulting Match Tables

Following the above archaeology-geosciences case of matching process and processing, the resulting match tables contain the references to conceptional and associated multi-dimensional knowledge in context of the object entities. The resulting start match table of object entities (Table V) contains entities and references on details of mythological and archaeological context.

Table V. Resulting Conceptual Knowledge Pattern Matching intermediate start ('UDC:90') match table (excerpt).

Object Entity	*Reference Data (excerpt)*
Poseidon	DESC MYTH SYN LOC UDC ... CITE:[27], [28], [29], [30]
Polybotes /-is	DESC MYTH SYN LOC UDC ... CITE:[27], [29]
Polyvotes /-is	DESC MYTH SYN LOC UDC ... CITE:[27], [29] (transcr.)

These entities contain descriptions, including transcriptions, transliterations, translations, mythology references, synonyms, location references, UDC references, and citation sources. The citations refer to respective associations of the figured programme with Poseidon and the giant Polybotes / Polybotis / Polyvotes / Polyvotis and further references to the details of mythological context of realia objects, respectively to Parthenon metopes (Acropolis, Athens).

The result match table of object entities (Table VI) contains entities and references on details of natural sciences context and georeferences.

Table VI. Resulting Conceptual Knowledge Pattern Matching intermediate result ('UDC:55') match table (excerpt).

Object Entity	*Reference Data (excerpt)*
Kos	DESC VOLC VNUM GRC LATLON UDC ...
Methana	DESC VOLC VNUM GRC LATLON UDC ...
Milos	DESC VOLC VNUM GRC LATLON UDC ...
Nisyros	DESC VOLC VNUM GRC LATLON UDC ...
Santorini	DESC VOLC VNUM GRC LATLON UDC ...
Yali	DESC VOLC VNUM GRC LATLON UDC ...

The entities in the respective match tables contain descriptions, volcanological references, volcano numbers, country references, latitude and longitude location references, UDC references, and further references. A resulting object is shown in Figure 10. Its respective media object entities refer to archaeology associated with Poseidon and Polyvotis.

```
Nisyros              [Volcanology, Geology, Archaeology]:
                     Volcano, Type: Strato volcano, Island,
                     Country: Greece, Subregion Name: Dodecanese Islands,
                     Status: Historical, Summit Elevation: 698\UD{m}. ...
                     Craters: ..., VNUM: 0102-05=, ...
                     %%IML: UDC:[911.2+55],[930.85],[902]"63"(4+38+23+24)=14
                     %%IML: UDC:[912] ...
                     %%IML: media:...{UDC:[911.2+55],"63"(4+38+23)}...jpg
                     Stefanos Crater, Nisyros, Greece.
                     LATLON: 36.578345,27.1680696
                     %%IML: GoogleMapsLocation: https://www.google.com/...@36
                      .578345,27.1680696,337m/...
                     Little Polyvotis Crater, Nisyros, Greece.
                     LATLON: 36.5834105,27.1660736 ...
```

Figure 10. Result object entity from Knowledge Resources: Nisyros object, Greece, containing media object entities and georeferences (excerpt).

As requested, the object contains/refers to latitude/longitude and conceptual knowledge, together with factual knowledge and media references.

Figure 11 shows media object entities based on the conceptual knowledge pattern matching process, an object entity at process start (Figure 11(a)), from archaeological artefacts, and a resulting reference object (Figure 11(b)), from natural objects. The media object entities and their context represent the result of the requested knowledge pattern matching, including respective georeferencing properties.

VIII. Integration modules for result context creation and georeferencing

Commonly, it is a challenging question how the integration of multi-disciplinary knowledge object instances and context can be achieved for further deployment.

A. Phonetic modules and values

The deployed implementation modules support a 'silken' selection [31], phonetic modules, which can be specified and closely integrated with conceptual context.

The knowledge resources can be used by any algorithm suitable for a defined workflow. One of the available module implementing a silken selection based on the Soundex principle is the `knowledge_sndx_standard` application. The historical Soundex [32] is a phonetic algorithm for indexing names by sound. The goal with this algorithm is to encode homophones so that they can be represented by the same resulting code in order to match persons' name despite differences in writing and spelling [33]. The basic algorithm mainly encodes consonants. Vowels are not encoded unless being a first letter. The U.S. Government is using a modified modern rule set [34] for purposes in census and archives. The original intention was to catch the English pronunciation, anyhow there are many different implementations in use today.

The selection module, modelled after the standard Perl implementation [35], for computing LX Soundex codes [36], can be adapted for different procedural context and programming concepts [37], [38]. The various workflows can define and integrate their own Soundex codes for different purposes and topics.

A large number of different modules and algorithms were developed for this research, even including various phonetic algorithms for respective content and context. Listing 11 shows a fully functional excerpt Perl source code module (`knowledge_sndx_grlat`) modelled after the standard Perl implementation and developed for the respective Greek and Latin context.

```perl
#!/usr/bin/perl
#
# knowledge_sndx_grlat -- (c) LX Project -- CPR
 1992, 2012, 2019
#

$string=$ARGV[0];
$sndx_nocode = undef;

sub knowledge_sndx_grlat
{
  local (@s, $f, $fc, $_) = @_;
  push @s, '' unless @s;

  foreach (@s)
  {
    $_ = uc $_;
    tr/A-Z//cd;

    if ($_ eq '')
    {
      $_ = $sndx_nocode;
    }
    else
    {
      ($f) = /^(.)/;
      tr/-AEHIOUWYBFPVCGJKQSXZDTLMNR
       /00000000011112202222223345556/;
      ($fc) = /^(.)/;
      s/^$fc+//;
      tr///cs;
      tr/0//d;
      $_ = $f . $f . $_ . '000';
      s/^(.{5}).*/$1/;
      $_=~s/BB/BV/;
      $_=~s/VV/BV/;
    }
  }

  wantarray ? @s : shift @s;
}

$code = knowledge_sndx_grlat $string;
print ("SNDX-grlat:$code:$string\n");

##EOF:
```

Figure 11. LX Soundex SNDX-grlat module Perl source code (excerpt), considering language dependent homophonic partial word transcriptions.

Table VII shows the result of the selection module for respective transcriptions in this information science case study.

TABLE VII. PHONETIC SOUNDEX SNDX-GRLAT CODES FOR TRANSCRIPTS OF POLYBOTES AND HOMOPHONIC PARTIAL WORDS (EXCERPT).

Object Entity	*Soundex Code (excerpt)*
Polybotes	`SNDX-grlat:PP413:Polybotes`
Polybotis	`SNDX-grlat:PP413:Polybotis`
Polyvotes	`SNDX-grlat:PP413:Polyvotes`
Polyvotis	`SNDX-grlat:PP413:Polyvotis`
-botes	`SNDX-grlat:BV320:-botes`
-botis	`SNDX-grlat:BV320:-botis`
-votes	`SNDX-grlat:BV320:-votes`
-votis	`SNDX-grlat:BV320:-votis`

The special phonetic code algorithm can consider possible transcriptions in respective languages for code results, which reflect a well comparable phonetic situation even for different transcriptions of the same entities.

(a) Metope, New Acropolis Museum, Athens, (CPR, DIMF, 2019).

(b) Volcano crater, island of Nisyros, Dodecanese Islands, Greece, (CPR, DIMF, 2019).

Figure 11. Result based on the conceptual knowledge pattern matching process, via intermediate match table (Table VI): (a) an artefact, metope (EAST VI), Parthenon, (Archaeology Digital Object Archive, 2019), and a resulting georeferenced object, (b) a natural object (Geosciences Digital Object Archive, 2019).

B. Knowledge reference tree: Phonetic and conceptual

Associated relations of object entities may span more than a distinctive conceptual knowledge reference group. Table VIII shows an excerpt of object entities and associated sources and reference data. The excerpt reflect presented the information science case study. Reference data excerpts list UDC code references and Soundex code references (SNDX-standard) for the named object entities.

Colour codes of the generated knowledge context reflect the results of the knowledge pattern matching, especially the result group (yellow) and result group contexts (green/blue).

TABLE VIII. KNOWLEDGE REFERENCE TABLE: UDC CODE REFERENCES AND PHONETIC (SOUNDEX, SNDX-GRLAT) ASSOCIATION (EXCERPT).

Object Entity and Sources	*KR*	*Reference Data (excerpts)*	
		UDC Code	*Soundex Code*
Parthenon, Acropolis, Athens	O	`UDC:902/904...`	`SNDX:PP635`
Polybotes, [27], [29] (transcr.)	O	`UDC:902/904...`	`SNDX:PP413`
			`SNDX:BV320`
Poseidon, [27], [28], [29], [30]	O	`UDC:902/904...`	`SNDX:PP235`
...			
Kos (Volcano)	C	`UDC:550.3...`	`SNDX:KK200`
Methana (Volcano)	C	`UDC:550.3...`	`SNDX:MM350`
Milos (Volcano)	C	`UDC:550.3...`	`SNDX:MM420`
Nisyros (Volcano)	CO	`UDC:550.3...`	`SNDX:NN262`
Polyvotis (Volc. Crater)	CO	`UDC:550.3...`	`SNDX:PP413`
			`SNDX:BV320`
Stefanos (Volc. Crater)	CO	`UDC:550.3...`	`SNDX:SS315`
Santorini (Volcano)	C	`UDC:550.3...`	`SNDX:SS536`
Yali (Volcano)	C	`UDC:550.3...`	`SNDX:YY400`
...			

Knowledge Resources (KR) can contain objects and entities of different organisation and structure, especially, collection (O) object entities and container (C) object entities. Reference data, especially UDC codes and phonetic Soundex codes, can be deployed for complex scenarios, which benefit from advanced referenced besides knowledge content and context of object entities and referenced sources.

There are two categories of object entities regarding a georeferencing context: Object entities, which cannot be logically attributed with a georeferencing and those, which have properties allowing georeferencing attributation. The first category (upper group) in this case is represented by a `UDC:902/904` context group, whereas the second category (lower group) is represented by a `UDC:550.3` context group.

The groups are linked by conceptual knowledge as some entities refer to both special collections and containers (CO). An additional, significant reference link between the group calculates from the phonetic `SNDX:PP413`/`SNDX:BV320` references.

C. Reference to automated context and georeferencing

Those associated object entities of different groups (Table VIII), which carry conceptual references and georeferencing can be selected by available properties and criteria, especially conceptual knowledge and phonetic means.

Table IX shows an excerpted result of the phonetic/conceptual knowledge reference tree process, the automatically associated georeferenced object entities.

TABLE IX. RESULT OF THE PHONETIC/CONCEPTUAL KNOWLEDGE REFERENCE TREE: GEOREFERENCED OBJECT ENTITIES (EXCERPT).

Object Entity	*Reference Data (excerpt)*	
	LATLON	
Kos (Volcano)	36.829	27.257
Methana (Volcano)	37.615	23.336
Milos (Volcano)	36.699	24.439
Nisyros (Volcano)	36.580	27.180
Parthenon, Acropolis, Athens	37.972	23.727
Polyvotis (Volc. Crater)	36.583	27.177
Santorini (Volcano)	36.404	25.396
Stefanos (Volc. Crater)	36.578	27.168
Yali (Volcano)	36.630	27.100

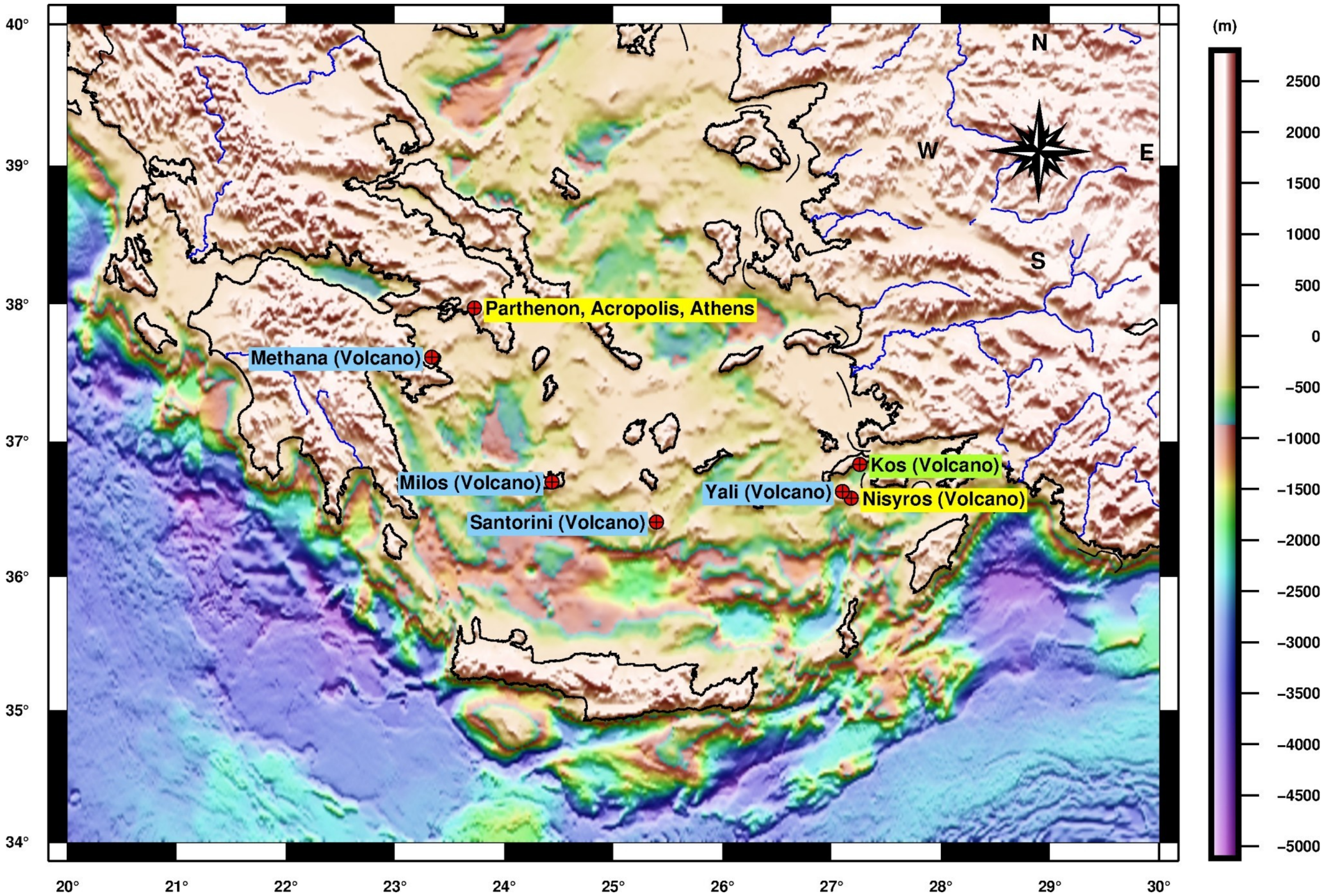

Figure 12. Automatically generated knowledge context (red bullet markers) of the conceptual knowledge pattern matching result group (yellow labels) and result group contexts (green/blue labels) in their topographic context, created based on georeferenced knowledge resources object entities and conceptual knowledge.

Consecutive context can be created by automatically generated mapping and visualisation modules, e.g., employing GMT routines, based on these results. Result context of the `UDC:902/904` context group are `UDC:550.3` context group object entities, which secondary context (Figure 12) is represented by respective geological and plate tectonics knowledge for the georeferenced area (Aegean Sea region). The new generated context integrates the various contexts and object entity representations in a multi-dimensional result. For these cases the module option is Mercator projection in order to provide a common base for comparisons of proper attributes and required flexibility.

Appropriate data was required for the topographic data related criteria. In the past, the georeferenced objects have been used with various data, e.g., with the Global Land One-kilometer Base Elevation Project (GLOBE) [39] and the 2-minute gridded global relief data (ETOPO2v2) [40].

For the required resolution of the results presented here, the knowledge resources had to be integrated with data based on the gridded ETOPO1 1 arc-minute global relief model data [41]. For special purposes data can be composed from various sources, e.g., adding Shuttle Radar Topography Mission (SRTM) data [42] from the Consultative Group on International Agricultural Research (CGIAR) [43].

The horizontal datum of ETOPO1 is World Geodetic System geographic, which was established in 1984 (WGS84) and later revised. The WGS84 specifications and references are provided by the National Geospatial-Intelligence Agency (NGA) [44] and as EPSG:4326 from the European Petroleum Survey Group Geodesy (EPSG) [45]. The vertical datum of ETOPO1 is "sea level". The source elevation data were not converted by the authors of ETOPO1 to a common vertical datum because of the large cell size of 1 arc-minute.

The Generic Mapping Tools (GMT) [46] suite application components are used for handling the spatial data, applying the related criteria, and for the visualisation.

IX. Discussion

The implemented method and the integration modules for result context creation and georeferencing has been a viable, efficient, and flexible solution in many case scenarios. Implementations are far not trivial but any discipline being able to ask questions as demonstrated should also be able to deploy the methodology and presented components for creating solid fundaments and practical solutions for challenging, complex scenarios, e.g., classification and dating of objects [47], geoscientific prospection, surveying [48], and knowledge [49], chorological and chronological context [50], can contribute to the fundaments of archeological and prehistorical cognition [51] and insight [52] regarding realia and abstract objects, knowledge, and contexts. The presented knowledge-based method and conceptual knowledge framework allow to address context very flexibly, e.g., in order to enable the metacognitive documentation of metacognitive and procedural knowledge of Geoscientific Information Systems or Geographic Information System analysis [53], filtering contextualised artistic representations [54] and managing object collections [55]. Knowledge-based approaches can also be beneficial without advanced knowledge resources, e.g., in cases of realia collections, information management and service oriented institutions and research data collection, e.g., The Digital Archaeological Record [56] of Digital Antiquity [57].

For example, in focus cases of archaeology, prehistory, and history context and georeferencing can further be supported by facet creation into more dimensions and also allows the application of a consistent conceptual base for description and fuzziness, beyond common auxiliaries and georeferencing. Spatial references beyond common auxiliaries of place [23] (Table IV), especially 'Places of the ancient and mediaeval world' (UDC:(3)) and 'Countries and places of the modern world' (UDC:(4/9)) can be created from the following tables of UDC code references.

Tables X and XI provide example excerpts of relevant main conceptual knowledge and details of UDC references used for conceptual mapping. For conceptual knowledge of place and spatial context the implementations requires to provide references to classification codes. The UDC provides references based on the common auxiliaries of place of the UDC [23] as excerpted here for facets of place and space, physiographic designation, and places from ancient to modern world.

TABLE X. CONCEPTUAL MAPPING REFERENCES WITH UDC CODES OF SPATIAL FEATURES / PLACE: AUXILIARIES OF PLACE (EXCERPT).

UDC Code	*Description*
UDC:(1/9)	Common auxiliaries of place.
UDC:(1)	Place and space in general. Localization. Orientation
UDC:(100)	Universal as to place. International. All countries in general
UDC:(1-0/-9)	Special auxiliary subdivision for boundaries and spatial forms of various kinds
UDC:(1-0)	Zones
UDC:(1-1)	Orientation. Points of the compass. Relative position
UDC:(1-2)	Lowest administrative units. Localities
UDC:(1-5)	Dependent or semi-dependent territories
UDC:(1-6)	States or groupings of states from various points of view
UDC:(1-7)	Places and areas according to privacy, publicness and other special features
UDC:(1-8)	Location. Source. Transit. Destination
UDC:(1-9)	Regionalization according to specialized points of view

TABLE XI. CONCEPTUAL MAPPING REFERENCES WITH UDC CODES OF SPATIAL FEATURES / PLACE: PHYSIOGRAPHIC DESIGNATION (EXCERPT).

UDC Code	*Description*
UDC:(2)	Physiographic designation
UDC:(20)	Ecosphere
UDC:(21)	Surface of the Earth in general. Land areas in particular. Natural zones and regions
UDC:(23)	Above sea level. Surface relief. Above ground generally. Mountains
UDC:(24)	Below sea level. Underground. Subterranean
UDC:(25)	Natural flat ground (at, above or below sea level). The ground in its natural condition, cultivated or inhabited
UDC:(26)	Oceans, seas and interconnections
UDC:(28)	Inland waters
UDC:(29)	The world according to physiographic features
UDC:(3/9)	Individual places of the ancient and modern world

The references, e.g., classification, facets, concordances, and textual description, are usable in all the procedures and steps and allow to consider and implement arbitrary flexibility of fuzziness. Entry points to relevant and associated knowledge may be in any disciplinary context due to the consistent framework of the UDC and the multi-disciplinary and multi-lingual Knowledge Resources.

In our practical research projects and implementations, deploying a modular integration of consequent knowledge resources' components and their development with means of conceptual knowledge pattern matching has proven to enable valuable solutions for challenging and complex cases of in many disciplines.

X. CONCLUSION

This research achieved to implement the goal of integrating knowledge resources' development and universal conceptual knowledge pattern matching for practical context creation and georeferencing of archaeological, prehistorical, and geoscientific object entities. Respective module implementations, components developments, and results of automatically generated and consistent knowledge context and georeferencing were shown.

The information science integration case study demonstrated the practical components and their coherence for creating context and generating context results, e.g., visualisation, cartographic and topographic context including advanced solutions of object entity selection for georeferencing. It must be emphasised that this research targets an information science case study for multi-disciplinary resources and context, and cannot be limited to plain principles of case studies of technical or engineering aspects.

The implementations successfully employ the method of knowledge pattern matching based on the CKPM methodology. Further, the knowledge based mining implementation successfully employs the UDC references in order to provide the required conceptual framework. The UDC references proved to provide an excellent core component, for universal, multi-disciplinary, and multi-lingual knowledge.

In this new context, UDC showed to have a perfect organisational structure of conceptual knowledge for practical, systematical use as well as for an efficient and flexible processing support, following respective knowledge forks for references while creating and keeping developing resources and conceptional knowledge consistent supported by its editions.

The rewarding benefits of the methodology allow disciplines, e.g., archaeologists, to work with complex and multi-disciplinary and multi-lingual knowledge references in a consistent way, which can by far no longer be dealt with manually or even with anachronistic practices. The knowledge-based methodology enables addressing arbitrary knowledge and facets and to create new and individual methods for dealing with complements, based on common knowledge resources.

The general framework includes targetting previously unidentified references to knowledge resulting from the referenced complements. The methodology provides a wide range of facilities for individual methods to deal with application scenarios, multi-dimensional object references, fuzziness and arbitrary fine granularity of knowledge and references and even references from external notations.

However, each of the deployed implementation components, e.g., classification, phonetic algorithms, and topographic context data, and GMT mapping, may require intensive study and even years of experience. The integration may even require additional levels of understanding and experience. Therefore, to significant extent, the will and seriousness to invest in and work with information science methods is an unavoidable precondition for any discipline to create successful solutions for millions of references and objects based on the presented methods.

In daily practice, the integration based on the new method provides excellent and sustainable conceptual documentation and enables to create associations and links between knowledge object entities, which cannot result with comparable consistency otherwise. Further, configuring knowledge ranges can be achieved in many ways, e.g., by limiting resources, configuring the pattern depths and widths, ranking and selection.

Future research on theory and practice will continue developing practical conceptual knowledge frameworks, especially for prehistory and archaeology and natural sciences context, suitable knowledge resources, knowledge patterns, and further means of integration modules and components.

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