From Knowledge and Meaning Towards Knowledge Pattern Matching: Creating, Processing, and Developing Knowledge Objects, Targeting Geoscientific Context and Georeferencing

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***Abstract*—This paper presents the results of the long-term research on advanced knowledge based mining enabled by conceptual knowledge frameworks. The paper presents the methodological base of a new 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. Examples in this specialised research concentrate on geoscientific context and georeferencing. The goal of this fundamental research is to create methods of knowledge pattern matching usable with many resources and data collections. The implemented practical approaches are for the first time publicly available with this paper.**

***Keywords*–Conceptual Knowledge Pattern Matching Methodology; Superordinate Knowledge Methodology; Advanced Data-centric Computing; UDC; Geoscientific and Geospatial Scenarios.**

I. Introduction

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 this research was the lack of suitable facilities for an advanced matching of 'meaning' when creating mining solutions in context of complex multi-disciplinary and multi-lingual Knowledge Resources. 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 [1]. 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. 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 [2].

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 [3]. 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.

The rest of this paper is organised as follows. Section II introduces the previous work and components. Sections III and IV present methodology, method, and implementation. Sections V and VI present the matching process and resulting tables. Section VII summarises conclusions and future work.

II. Previous work, components, and resources

The fundaments of terminology and understanding knowledge are layed out by Aristotle being an essential part of 'Ethics' [4]. Information sciences can very much benefit from Aristotle's fundaments and a knowledge-centric approach [3] but for building holistic and sustainable solutions, supporting a modern definition of knowledge [5], they need to go beyond the available technology-based approaches and hypothesis [6] 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 [7] enabling the creation of new object and entity context environments, e.g., implementing methods for knowledge mining context.

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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 are methodology, implementation, and realisation [8]. 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 [9].

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) [10] 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 [10] released by the UDC Consortium under a Creative Commons license [11]. 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) [12] syntax for specifying common string patterns and Perl [13] for component wrapping purposes with this case study.

III. 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, [14]). Creating facets and patterns can also make use of the common auxiliary signs being part of the UDC framework [15]. 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 [16] 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 [17] 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.
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 [18], 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 [19], 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.

IV. 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.

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V. 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.

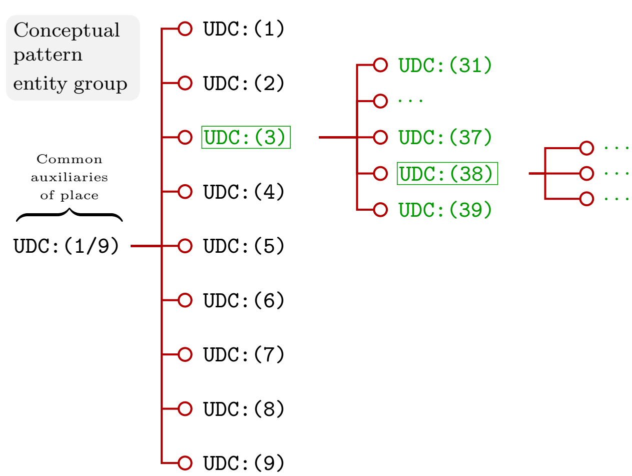

Figure 7. Matching process: Primary, decimal (UDC) conceptual knowledge forks, auxiliaries of spatial features and place (excerpt).

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.

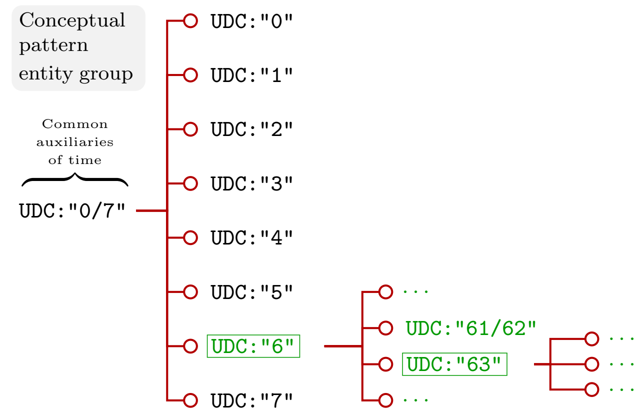

Figure 8. Matching process: Primary, decimal (UDC) conceptual knowledge forks, auxiliaries of time (excerpt).

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).

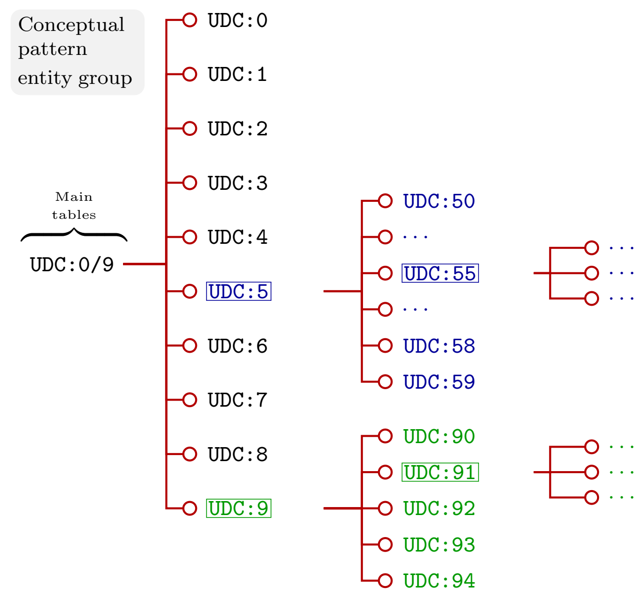

Figure 9. Matching process: Primary, decimal (UDC) conceptual knowledge forks, main tables, including earth sciences and geography (excerpt).

The processing successfully follows the "Earth sciences" and "Geography" forks. These procedures referencing to a formalised [20], 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 [21]. In the mathematical domain, removing is mostly formalised by subtraction [22]. In general, any universal conceptual knowledge framework can be used, which enables a systematical processing and which is universal and consistent.

VI. 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:[23], [24], [25], [26]
Polybotes/-is	DESC MYTH SYN LOC UDC ... CITE:[23], [25]
Polyvotes/-is	DESC MYTH SYN LOC UDC ... CITE:[23], [25] (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 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.

VII. Conclusion

This research achieved the goal to create a new method of knowledge pattern matching based on the CKPM methodology. The knowledge based mining implementation employed 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.

In daily practice, the new method provides excellent and sustainable conceptual documentation and enables to create associations and links between knowledge object entities, which cannot result 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 suitable knowledge resources and knowledge patterns.

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(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).

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