Practice of Formalised Conceptual Knowledge Complements Realising Multi-disciplinary Knowledge Resources for Natural Sciences and Humanities

Claus-Peter Rückemann
Westfälische Wilhelms-Universität Münster (WWU), Germany;
Knowledge in Motion, DIMF, Germany;
Leibniz Universität Hannover, Germany
Email: ruckema@uni-muenster.de

***Abstract*—The results and insights in the practice of multi-disciplinary knowledge resources presented in this article are based on the research and developments conducted during the last years. Many multi-disciplinary and practical geo-spatial data and application solutions require to employ integrated resources from disciplines of natural sciences and humanities to exploit holistically complex knowledge scenarios. In many cases, data and algorithms as well as workflows have to be created and tackled individually. The goal of this paper is to illustrate examples of integrated knowledge based on the ongoing research to create sustainable and innovative resources ans a comprehensive tool base of conceptual knowledge in geo-spatial application scenarios and beyond, for arbitrary knowledge context in any media. The solution should be complementary to the commonly available geo-spatial features and should fulfill a range of further criteria, especially for a coherent system of knowledge, multi-disciplinary, and data-centric. The result should allow to create and refer to facetted knowledge focussed on geo-spatial scenarios. The paper presents a range of multi-disciplinary knowledge complements in their formalised common conceptual knowledge and the results of an implementation based on the fundamental methodology of superordinate knowledge. The resulting solution is targeting geo-spatial application scenarios and has been used for many practical implementations over more than three decades. The resulting comprehensive subset of conceptual knowledge reference divisions, which was created from this long-term research, is available and first published with the cited research.**

Keywords*–Conceptual Knowledge Complements; Multi-disciplinary Knowledge Resources' Practice; Superordinate Knowledge Methodology; UDC; Advanced Data-centric Computing.

I. Introduction

This extended research is based on the practical subset of conceptual knowledge, which was presented at the GEOProcessing 2019 conference in Athens, Greece [1]. Responding to the major interests from the public discussion in Athens, this research goes beyond plain methods and the limited view of 'data' and illustrates the formalisation and conceptual knowledge complements, the fundaments and organisation of realising multi-disciplinary knowledge resources, based on the Principles of Superordinate Knowledge.

The motivation of this research is to show a representative compilation of components, which are integral components in complex implementation scenarios and which are under creation and development for significant periods of time.

This paper presents different types of multi-disciplinary Knowledge Resources from complementary discipline collections and resources in reference with geo-spatial disciplines. The paper especially discusses the practice of formalised conceptual knowledge complements created with multi-disciplinary collections, containers, and referenced resources. It is a truth universally acknowledged, that geo-spatial disciplines are specialised and very much concentrating on providing solutions and tools for spatial data. When it gets to more complex situations, then, spatial data based on numerical coordinate reference systems and domain only approaches may not be sufficient. This is, for example, the case when describing the target knowledge with mathematical spacial facets and dimensions is not sufficient.

Many information and context maybe lost when knowledge is handled as plain data and mapped to preexisting attributes and categories. This is the case when a more holistic and more fundamental approach should be considered. In practice, associating different objectives and intentions, systematic knowledge, and physical features with knowledge, from methodology to implementation and realisation, can provide valuable solutions. The principles of superordinate knowledge provide such fundaments, from methodology to realisation.

The resulting solution is a comprehensive subset of conceptual knowledge, which should be complementary to the commonly available geo-spatial topologies, taxonomies, and features and the multi-disciplinary context. In consequence, the means of describing spatial data, objects, entities, and context should be substantially extended.

The rest of this paper is organised as follows. Sections II and III introduce the state of the art and motivation and discuss previous work, components, and used resources. Sections IV and V discuss basic practical examples of conceptual knowledge formalisation and present representative examples of multi-disciplinary knowledge complements. Section VI presents the resulting conceptual knowledge solution. Sections VII and VIII evaluate the resulting subset, directly related implementations, research, development, and cases studies and summarise the lessons learned, conclusions, and future work.

II. State of the art and motivation

It is most beneficial to have universal means to describe and document knowledge over all complements of the Knowledge Resources and being able to support formalisation. For advanced applications, it is also beneficial to have means, which can deal as conceptual knowledge framework.

Formalisation is the process of creating a defined set of rules, allowing a formal system to infer theorems from axioms. Formalised conceptual knowledge complements can be created employing references to consistent conceptual knowledge, here illustrated by references to UDC and UDC concordances. Sustainable knowledge and resources management was successfully implemented for environmental information and computation [2] along with a basis for environmental management, the International Organization for Standardization (ISO) 14000 series containing standard recommendations for assessment, evaluation, life cycle analysis, communication, and auditing [3]. Complementary implementations were also successfully created for advanced mathematical-computational scenarios [4].

Geo-spatial practice is focussed on providing cartographic means for certain space and environment. Widely employed tools are Geoscientific Information Systems and Geographic Information Systems. Most of these tools use geo-referenced data in order to organise and reference information. Available topologies can also provide for the categorisation of geo-spatial entities. All together these means are very limited when seen in a larger context as required for many complex application scenarios. Regarding that, one of the major deficits is the lack of a consistent and holistic knowledge concept. The fundaments of terminology and understanding knowledge are layed out by Aristotle [5], being an essential part of 'Ethics' [6]. Information sciences can very much benefit from Aristotle's fundaments and a knowledge-centric approach [7] 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.

In sciences, observation is one of the most important fundamental tasks [10]. But, as John Burroughs expressed "There is nothing in which people differ in more than in their powers of observation. Some are only half alive to what is going on around them." [11]. Triggered by the results of a systems cases study, it is obvious that superordinate systematic principles [12] are still widely missing in practice and education. Making a distinction and creating interfaces between methods and the implementation applications [13], the results of this research are illustrated here along with the practical example of the Knowledge Mapping methodology [14] enabling the creation of new object and entity context environments, e.g., implementing methods for knowledge mining context. This motivating background allows to build methods for knowledge mapping on a general methodological fundament.

The Organisation for Economic Co-operation and Development (OECD) has published principles and guidelines for access to research data from public funding [15]. The principles and guidelines are meant to apply to research data that are gathered using public funds for the purposes of producing publicly accessible knowledge. In this context, the OECD especially addresses knowledge, re-use, and knowledge generated from re-use. The means to achieve such recommendations even for complex scenarios is to use the principles of Superordinate Knowledge, which integrate arbitrary knowledge over theory and practice. Core assembly elements of Superordinate Knowledge [12] are:

- Methodology.
- Implementation.
- Realisation.

Separation and integration of assemblies have proven beneficial for building solutions with different disciplines, 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 [2]. The conceptual knowledge reference divisions presented here are the result from more than three decades of scientific research in information science and multi-disciplinary knowledge.

III. Components, formalisation, and design

There is a number of criteria, which are of major significance for advanced and complex scenarios, especially, the conceptual knowledge and the knowledge resources have to provide. The resulting solution should fulfill a range of criteria in order to provide a most sustainable, flexible fundament, e.g.:

- Covering a coherent system of knowledge, supporting universal knowledge.
- Consistent implementation, quasi-standardised.
- Providing facetted conceptual knowledge features.
- Multi-disciplinary knowledge spectrum.
- Features for multi-lingual implementation.
- Data-centric implementation / method.
- Extensible concept.

Therefore, these criteria should allow advanced features, for example:

- Documentation of data, objects, scenarios, concepts, algorithms,
- universal context of knowledge criteria for all kind of knowledge in any media,
- knowledge documentation,
- knowledge consistent integration of publications and research data,
- knowledge mining,
- wide range of flexible implementation potential,
- supporting workflow features and documentation.

The Knowledge Resources can embrace a wide range of different types of complements, e.g., collections, containers, and other referenced resources.

These complements can be organised individually, e.g., due to the fact that often each collection maybe a long-term or even open-end matter of development, e.g., for an individual disciplines' task, research council or business.

In consequence, the primary design strategies of the core Knowledge Resources require a focus on data-centricity. Therefore, a central goal are sustainable, portable structures, which can be kept vital and knowledge-consistent with future developments.

The use of multi-disciplinary and consistent conceptual knowledge frameworks also contributes to the sustainable creation of sustainable concordances and solutions. For example, advanced knowledge discovery and computing can be realised very forward-looking and efficient when based on Knowledge Resources, concordances, and classification [16].

According with these strategies and goals, the selection of conceptual frameworks and integration is essential in order to ensure that conceptual references can be seamlessly developed with the development of growing Knowledge Resources in flexible and sustainable ways. The components and feature selection for a practical, formalised implementation are described with the following passages.

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 facility for consistently describing knowledge is a valuable quality, especially conceptual knowledge, e.g., using the Universal Decimal Classification (UDC) [17]. The UDC can be used for consistently formalising universal conceptual knowledge in multi-disciplinary and multi-lingual context.

The UDC 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. Therefore, the UDC represents a most flexible facetted classification system for all kinds of knowledge in any media. The UDC provides 70,000 subdivisions, in 50 languages, which provides more than 3 million entries and verbal descriptions. The UDC is up to now internationally used in 130 countries, for 150,000–200,000 document collections worldwide. The classification has shown up being especially important for complex, facetted, multi-disciplinary, and long-term classification, e.g., with Knowledge Resources. The UDC is the best publicly available implementation of conceptual knowledge to illustrate the width and depth of knowledge dimensions. The UDC allows an efficient and effective processing of knowledge data and provides facilities to obtain a universal and systematical view on classified objects. Operational areas include author-side content classifications and museum collections, e.g., with documentation of resources, library content, bibliographic purposes on publications and references, for digital and realia objects. The Knowledge Resources objects and entities can refer to any conceptual knowledge, e.g., main UDC-based classes, which for this publication are taken from the multi-lingual UDC summary [17] released by the UDC Consortium under a Creative Commons license [18]. 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. Symbolism and meaning have significant value for any application in information science [19]. Object entities can be associated with symbolism, which can also be referred to conceptual knowledge [20]. Observation and experience are essential [21] with the cognition process and the required referencing.

Multi-disciplinary Knowledge Resources have been designed, created, and developed with various scenarios and realisations over the last decades. Figure 1 shows the complements diagram of core resources and their conceptual organisation and implementations. The major complements consist of application resources and components, knowledge resources, and originary resources and sources.

The Knowledge Resources are in focus of this research. They can contain all the relevant conceptual knowledge references for the complements. The Knowledge Resources are flanked by application resources and components, which are based on module implementations and program components. Associated implementations imply scripts, bytecode and executables, sources from various high level languages. Implementations range from individual developments to common third party components.

The originary resources and sources imply realia and reference targets, which range from objects in libraries and museums to in situ objects.

The central Knowledge Resources, which are discussed in the research, cover the complements of factual, conceptual, procedural, and metacognitive knowledge. For this research, we are presenting examples of different content implementations, especially collections, containers, and referenced resources.

There are no limitations for the conceptual knowledge referenced in collections, containers, and referenced resources. However, a standard multi-disciplinary, multi-lingual classification is the UDC, which can be consistently used with all different types of implementations.

The UDC is used for any conceptual description, providing arbitrary means, e.g., for facetted classification, conceptual inter-references between objects, object association based on verbal description.

IV. Basic practical examples of formalisation

A. Required conceptual knowledge features

Data and objects result from public, commonly available, and specialised Knowledge Resources. The Knowledge Resources are containing factual and conceptual knowledge as well as documentation and instances of procedural and metacognitive knowledge. These resources contain multi-disciplinary and multi-lingual data and context. UDC provides auxiliary signs [22], which represent kinds of standardised "operations". UDC allows the creation of facetted knowledge using these features. The conceptual knowledge in focus

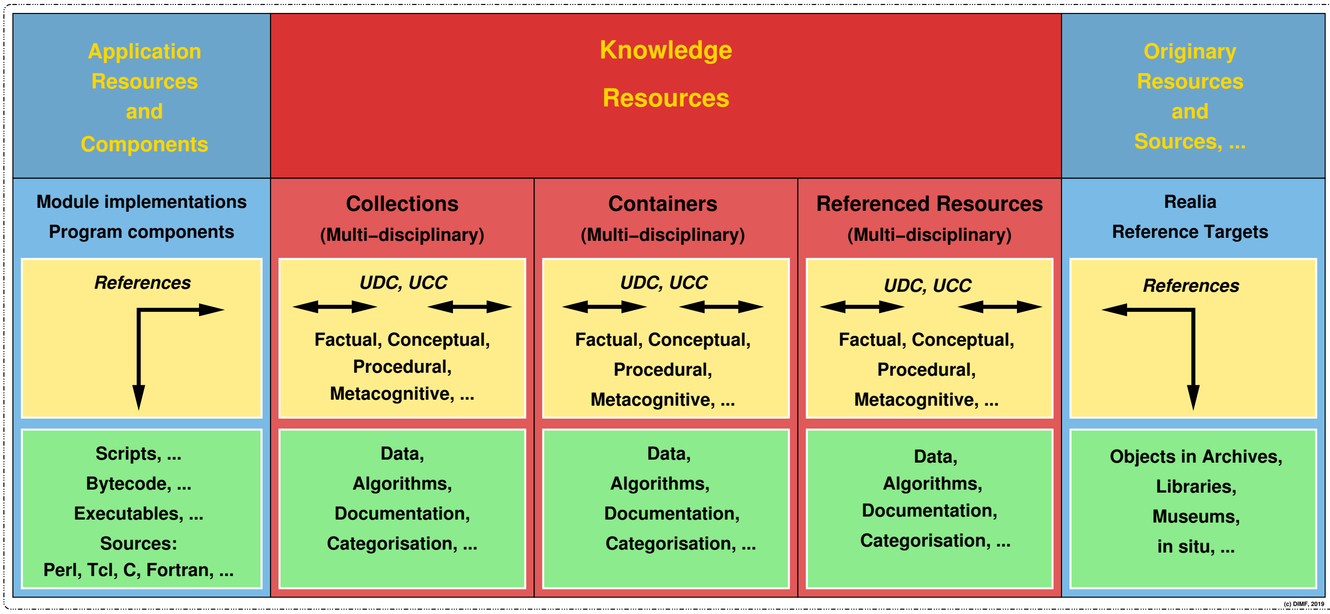

Figure 1. Multi-disciplinary Knowledge Resources: Complements diagram of core resources and their conceptual organisation and implementations. The three different types of Knowledge Resources discussed: Collections, containers, and referenced resources. Conceptual knowledge is illustrated via UDC and UCC.

requires to provide references to any universal knowledge context. References to UDC codes are capable to provide all the required context. The main tables provide an entry point to universal knowledge context [23]. For practical use, classification references can refer to UDC reference codes based on science and knowledge organisation [24]. For conceptual knowledge of place and spatial context the implementation requires to provide references to classification codes. The UDC provides references based on the common auxiliaries of place of the UDC [25]. In that context, besides universal knowledge, additional closely related references are required. UDC can provide appropriate references, e.g., geodesy, surveying, photogrammetry, remote sensing, cartography (UDC:528) [26] and geography, exploration, travel (UDC:910) [27], and nonliterary, nontextual representations of a region (UDC:912) [28].

B. *Examples of conceptual knowledge application*

Examples of conceptual knowledge reference divisions according with UDC (UDC:913, Regional geography, [29]; UDC:94, General history, [30]; UDC:(1/9), Common auxiliaries of place, [25]) and UDC conventions are shown in the following four small sample groups:

UDC:913(3)	⇒ Geography of the ancient world
UDC:913(3/9)	⇒ Geography of the individual regions and countries of the ancient and modern world
UDC:94(3)	⇒ History of the ancient world
UDC:94(3/9)	⇒ History of individual places of the ancient and modern world
UDC:94(37)	⇒ History of ancient Rome and Italy (to 5th century)
UDC:94(38)	⇒ History of ancient Greece
UDC:(37)(24)	⇒ Ancient Rome and Italy, below sea level
UDC:(38)(24)	⇒ Ancient Greece, below sea level

A little more complex facetted example, a single data object entity of a ship wreck realia as referred in a container of extended Knowledge Resources, is shown in Figure 2.

```
Lindos [Archaeology, Geophysics, Remote Sensing,
 Seafaring]:
 Greek city, Rhodos Island, Dodekanese, Greece. ...
 Object: Ship wreck.
 Object-Type: Realia object.
 Object-Location: 500\UD{m} SE of Hagios Pavlos Harbor.
 %%IML: UDC:[902+903+...+904]+629.5+(38)+(4)+(24)...
 %%IML: cite: YES 19810000 {LXK:Lindos; Rhodes; Ancient
  Greece; Archaeology; Artefacts; Ship wreck;} {UDC:...}
  {PAGE:--45..--58} LXCITE://Nikolitsis:1981:Rhodos
 %%IML: ...
 %%IML: OSMLocation: https://www.openstreetmap.org
  /...=36.08...%2C28.08...
 %%IML: GoogleMapsLocation: http://maps.google.com/maps
  ...=...,...
```

Figure 2. Knowledge Resources, conceptual spatial and geo-references: Lindos object with ship wreck entity, Rhodes, Greece (excerpt).

Passages not relevant for demonstration and not adequate for privacy and safety reasons were shortened to ellipses. The object entity contains documentation, object categories and factual data, conceptual data references, a source reference [31], and data for geo-references. The conceptual knowledge comprises details of non geo-spatial domains, e.g., from main tables UDC:6 and UDC:9, and from geo-spatial context, e.g., auxiliary tables for place and space UDC:(24) UDC:(3/9). For this case, the object entity references can be resolved as:

UDC:902	⇒	Archaeology
UDC:903	⇒	Prehistory. Prehistoric remains, artefacts, antiquities
UDC:904	⇒	Cultural remains of historical times
UDC:629.5	⇒	Watercraft engineering. Marine engineering. Boats. Ships. Boatbuilding and shipbuilding
UDC:(38)	⇒	Ancient Greece
UDC:(4)	⇒	Europe
UDC:(24)	⇒	Below sea level. Underground. Subterranean

The references can hold further details and sub-contain additional information, e.g., UDC:903 further refers to artefacts in more detail. For a wider and deeper view, we have to refer to a number of successful projects, which were conducted by the author's group and various collaborators over the last decades. All these implementations are significantly based on the solution presented here.

V. Implementation of knowledge complements

Example objects from the practical implementations of formalised conceptual knowledge complements for disciplines are shown in the following paragraphs. The examples show the range of contributing disciplines and the significance of features for a consistent conceptual knowledge implementation. Only excerpts of English language objects are shown for these examples. Anyhow the complements have to be available in multi-lingual instances of which the conceptual reference implementation must be able to handle. With the shown solution, the conceptual complements support about 50 languages.

A. Complementary environmental information

An example object from the environmental knowledge resources' complements is shown in Figure 3.

```
2004/35/EC [Environment, Climate, GIS, ...]:
 Directive 2004/35/EC, European Community, Environmental
  Liability Directive.
 %%SRC: 20050000 CPR
 The Environmental Liability Directive [ELD] 2004/35/EC
  is one of the most important instruments ...
 %%IML: UDC:502/504,551.581/551.582,341.1,(4)
 s. also ELD, EMS
```

Figure 3. Knowledge Resources, factual and conceptual complements: Environmental information, directives (excerpt).

The object carries factual knowledge and respective conceptual knowledge references. The full object refers to environmental information, climate information, and spatial context.

B. Complementary natural sciences

An example object from the natural sciences knowledge resources' complements is shown in Figure 4.

```
diffraction [Physics, Optics]:
 Deviation of a part of a ray due to the wave character
  of radiation.
 Diffraction occurs if rays hit the edge of an opaque
  obstacle.
 %%SRC: 1994, 2001, 2013 CPR
 %%IML: UDC-Object:535+535.42+550.3+550.8
 %%SRC: 2009 CPR
 %%IML: keyword-Context: KYW :: Physics, Optics, Waves,
  Seismics, Geophysics, Resolution, Exploration, Earth
  crust, Earth surface, Applied Geosciences, Archaeology,
   Scientific Computing, Data Processing, Statistics,
  Modelling
 %%SRC: 2010 CPR
 %%IML: code: YES 19940401 {LXC:DETAIL----} {UDC:(0.034)
  ,004.432,004.43.FOR} LXDATASTORAGE:///home/cpr/...
 %%IML: UDC-Object:(0.034),004.432,004.43.FOR
 %%IML: objectcomment: {PROGRAMCODE-name:
  diffam}
 %%IML: objectcomment: {PROGRAMCODE-language:
  Fortran77}
 %%IML: objectcomment: {PROGRAMCODE-compilation:
  Makefile}
 %%IML: objectcomment: {PROGRAMCODE-compiler:
  xlf}
 %%IML: objectcomment: {PROGRAMCODE-operatingsystem:
  AIX}
 %%IML: objectcomment: {PROGRAMCODE-compiler:
  g77}
 %%IML: objectcomment: {PROGRAMCODE-operatingsystem:
  Linux}
 %%IML: objectcomment: {PROGRAMCODE-compiler:
  g77}
 %%IML: objectcomment: {PROGRAMCODE-virtualsystem:
  VMWARE SuSE Linux}
 %%IML: objectcomment: {PROGRAMCODE-routine:
  ...}
 %%IML: objectcomment: {PROGRAMCODE-framework:
  ...}
 %%IML: objectcomment: {PROGRAMCODE-workflow:
  ...}
 %%IML: objectcomment: {PROGRAMCODE-usage:
  ...}
 %%IML: cite: NO  20130000 {LXK:Diffraction Amplitudes;
  Optics; Seismics;} {UDC:...} {PAGE:----..----} LXCITE:
  //Rueckemann:2013:Diffraction
```

Figure 4. Knowledge Resources, factual and conceptual complements: Natural sciences, phenomena, formalisation, and methods (excerpt).

The object carries factual knowledge and respective conceptual knowledge references. The conceptual knowledge refers to optics, diffraction, geophysics, applied geology, geological prospecting and exploration, and interpretation of results.

C. Complementary archaeology and mythology

An example object from the object collections for natural sciences and humanities of the knowledge resources' complements is shown in Figure 5.

```
Hephaistos [Archaeology, Volcanology]:
 (greek) God.
 Greek god, forger for the gods.
 Later god of fire and the forge.
 %%SRC: 1990 CPR
 compare Vulcanus
 %%IML: UDC:[902+903+904]:[25+930.85]"63"(4)(093)=14
```

Figure 5. Knowledge Resources, factual and conceptual complements: Volcanology, archaeology, and mythology (excerpt).

The object carries factual knowledge and respective conceptual knowledge references. The conceptual knowledge refers to archaeology, prehistory, prehistoric remains, artefacts, antiquities, cultural remains of historical times, religions of antiquity, minor cults and religions, history of civilization, cultural history, archaeological, prehistoric, protohistoric periods and ages, auxiliaries of place (Europe) historical sources, Greek (Hellenic) language.

An associated example object from the object collections for natural sciences and humanities of the knowledge resources' complements is shown in Figure 6.

```
Kukulkán [Archaeology]:
 (maya.) God.
 Feather Snake.
 Popol Vuh.
 %%SRC: 1990 CPR
 %%IML: UDC:[902+903+904]:[25+930.85]"63"(7)(093)=84/=88
 Syn.: Kukulcán
 s. Popol Vuh, Chichén Itzá
```

Figure 6. Knowledge Resources, factual and conceptual complements: Archaeology, mythology (excerpt).

The object carries factual knowledge and respective conceptual knowledge references. The conceptual knowledge refers to comparable context as the previous object but extends the knowledge matrix by auxiliaries of place (North and Central America) and Central and South American indigenous languages.

D. Complementary location

An associated example object from the object collections for location references of the knowledge resources' complements is shown in Figure 7.

```
L'Anse-aux-Meadows [Archaeology]:
 Viking Settlement, Newfoundland, America.
 Founded before \isodate{1000}{}{}.
 %%IML: UDC:[904]:[930.85](23)(4)(7)
 %%SRC: 1992 CPR
```

Figure 7. Knowledge Resources, factual and conceptual complements: Archaeology, physical and geographic locations (excerpt).

The object carries factual knowledge and respective conceptual knowledge references. The conceptual knowledge refers to cultural remains of historical times, history of civilization, Cultural history, North and Central America – Europe association, and above sea level context.

E. Further complementary knowledge gamut

Universal knowledge from any context is further available in order to support processes and applications besides these small examples from complementary knowledge resources. The disciplines themselves are not limited and span all knowledge, e.g., natural sciences, seismics and seismology, cartography, remote sensing, georeferences, volcanology, mineralogy, physics, chemistry, geology, mathematics,, archaeology, planetology, astrophysics, space research, biology, palaeontology, geography, religion and mythology, art, linguistics, documentation, publication.

In the context of application they also have to build facets, embracing standards and languages as well as referencing arbitrary factual knowledge, e.g., cities, countries, researchers, institutions, bibliographies.

Therefore, the comprehensive subset for geo-spatial application scenarios, which is the result of this research does have to handle these references.

F. Creation of objects and conceptual knowledge

In respect of application scenarios, e.g., object processing, the value of concordances may be reminded. Practical creation of objects has shown to be most efficient when three different categories of creation are considered:

- Manually created objects,
- Hybrid (semi-automatically) created objects, and
- Automatically created objects.

In any case creating objects is supported by universal classification, e.g., references to UDC. Therefore, that can also be applied for the creating concordances with objects.

We use a well known object for demonstration, which is referenced in the same container with all volcano objects. The listing in Figure 8 shows an instance of a simple object excerpt from an object collection. The excerpt shows keywords, content, e.g., including references, documentation, factual knowledge, and conceptual knowledge.

```
Vesuvius [Volcanology, Geology, Archaeology]:
 (lat.) Mons Vesuvius.
 (ital.) Vesuvio.
 (deutsch.) Vesuv.
 Volcano, Gulf of Naples, Italy.
 Complex volcano (compound volcano).
 Stratovolcano, large cone (Gran Cono).
 Volcano Type: Somma volcano,
 VNUM: 0101-02=,
 Summit Elevation: 1281 m.
 The volcanic activity in the region is observed by the
 Osservatorio Vesuviano. The Vesuvius area has been
 declared a national park on 1995-06-05.
 The most known antique settlements at the Vesuvius are
 Pompeji and Herculaneum.
 Syn.: Vesaevus, Vesevus, Vesbius, Vesvius
 s. volcano, super volcano, compound volcano
 s. also Pompeji, Herculaneum, seismology
 compare La Soufrière, Mt. Scenery, Soufriere
 ...
 UDC:[911.2+55]:[930.85]:[902]"63"(4+37+23+24)=12
 ...
 UCC:UDC2012:551.21
 UCC:UDC2012:551
 UCC:UDC2012:902/908
 UCC:MSC2010:86,86A17,86A60
 UCC:LCC:QE521-545
 UCC:LCC:QE1-996.5
 UCC:LCC:QC801-809
 UCC:LCC:CC1-960,CB3-482
 UCC:PACS2010:91.40.-k
 UCC:PACS2010:91.65.-n,91.
```

Figure 8. Processed instance of a simple object (excerpt) from an object collection.

Both classification and concordances, the Universal Classified Classification (UCC), were collected and created semi-automatically over a period of time. The rest of the object was created manually.

The listing in Figure 9 shows an instance of a simple container entry excerpt from a volcanological features container, in a representation, which can be input for processing workflows.

The excerpt shows a representation of conceptual knowledge for the container and various factual knowledge. The data was collected and created semi-automatically over a period of time.

```
CONTAINER_CONCEPTUAL_KNOWLEDGE: UCC:UDC2012:551.21
CONTAINER_CONCEPTUAL_KNOWLEDGE: UCC:UDC2012:551
CONTAINER_CONCEPTUAL_KNOWLEDGE: UCC:UDC2012:551
 .2,551.23,551.24,551.26
CONTAINER_CONCEPTUAL_KNOWLEDGE: UCC:UDC2012:902/908
CONTAINER_CONCEPTUAL_KNOWLEDGE: UCC:MSC2010:86,86A17,86
 A60
CONTAINER_CONCEPTUAL_KNOWLEDGE: UCC:LCC:QE521-545
CONTAINER_CONCEPTUAL_KNOWLEDGE: UCC:LCC:QE1-996.5
CONTAINER_CONCEPTUAL_KNOWLEDGE: UCC:LCC:QC801-809
CONTAINER_CONCEPTUAL_KNOWLEDGE: UCC:LCC:CC1-960,CB3-482
CONTAINER_CONCEPTUAL_KNOWLEDGE: UCC:PACS2010:91.40.-k
CONTAINER_CONCEPTUAL_KNOWLEDGE: UCC:PACS2010:91.65.-n,91.
CONTAINER_CONCEPTUAL_KNOWLEDGE: UCC:PACS2010:91.40.Ge
 ,91.40.St,91.40.Rs,*91.45.C-,*91.45.D-,90
...
CONTAINER_OBJECT_EN_ITEM: Vesuvius
CONTAINER_OBJECT_DE_ITEM: Vesuv
CONTAINER_OBJECT_EN_PRINT: Vesuvius
CONTAINER_OBJECT_DE_PRINT: Vesuv
CONTAINER_OBJECT_EN_COUNTRY: Italy
CONTAINER_OBJECT_DE_COUNTRY: Italien
CONTAINER_OBJECT_EN_CONTINENT: Europe
CONTAINER_OBJECT_DE_CONTINENT: Europa
CONTAINER_OBJECT_XX_LATITUDE: 40.821N
CONTAINER_OBJECT_XX_LONGITUDE: 14.426E
CONTAINER_OBJECT_XX_HEIGHT_M: 1281
CONTAINER_OBJECT_EN_TYPE: Complexvolcano
CONTAINER_OBJECT_DE_TYPE: Komplex-Vulkan
CONTAINER_OBJECT_XX_VNUM: 0101-02=
```

Figure 9. Processed instance of a simple container entry (excerpt).

The conceptual knowledge of several concordances' references is exported into this representation and illustrates how to integrate conceptual knowledge implementations.

The conceptual knowledge is a matter of more detailed discussion in the next subsections and sections. The excerpts have been processed with the appropriate `lx_object_volcanology` and `lx_container_volcanology` interfaces, selecting a number of items and for the container also items in English and German including a unique formatting.

The resources' access and processing can be done in any programming language, assuming that the interfaces are implemented. For example, combining scripting, filtering, and parallel programming can provide flexible approaches.

VI. Resulting conceptual knowledge solution

Table I contains the compilation of a general comprehensive subset of resulting major conceptual knowledge reference divisions for geo-spatial application scenarios. All the conceptual knowledge reference divisions presented are referring to UDC codes, which have been made publicly available. Here, "UDC:" is the designated notation of references used with Knowledge Resources and objects in ongoing projects. The UDC illustrates the width and depth of knowledge dimensions. The full details of organisation and knowledge are available from the UDC. As far a possible, the original verbal descriptions (English for demonstration) were taken, even if the writing of terms and words may differ from the practice used for the rest of this paper. The resulting conceptual knowledge solution comprises a most comprehensive knowledge compendium of geo-spatially dominated facetted knowledge, which can be effectively and efficiently used in geo-spatial application scenarios. Besides the level of detail and arbitrary facetted knowledge, the respective conceptual knowledge reference divisions provide a focussed discipline coverage while spanning a large width and depth of knowledge reference divisions. For example, let us take an additional view on depth for UDC:004 (Computer science and technology. Computing. Data processing), UDC:51 (Mathematics), and UDC:528 (Geodesy. Surveying. Photogrammetry. Remote sensing. Cartography).

Besides the shown references, UDC:004 also comprises important subdivision context of data and structure, e.g., data handling (UDC:004.62), files (UDC:004.63), databases and their structures (UDC:004.65), and systems for numeric data (UDC:004.67). For practical references, UDC:004 can be used to also hold references to many application scenarios, e.g., algorithms for program construction, low level as well as high level and problem oriented languages, knowledge representation, artificial intelligence application systems, intelligent knowledge-based systems. For practical references with mathematical, geometrical, and topological context, UDC:51 can be used to also hold references to fundamental and general considerations of mathematics, number theory, algebra, geometry, topology, analysis, combinatorial analysis, graph theory, probability, mathematical statistics, computational mathematics, numerical analysis, mathematical cybernetics, operational research as well as mathematical theories and methods. For practical references with geoscience and spatial disciplines, UDC:528 can be used to also hold references to a much deeper discipline based knowledge, e.g., fundamentals derived from potential theory, level surfaces, geoids, geometric/static methods, use of longitudinal and latitudinal measurements, gravity measurement, astro-geodetic determination of position, geographical coordinates, topographic surveying, engineering surveys, special fields of surveying, applications of photogrammetry, fundamental and physical principles, data processing, and interpretation.

The result of conceptual knowledge reference divisions based on the methodology of superordinate knowledge is complementary to geo-spatial topologies and geo-referencing. It can be used complementary with any geoscientific and geospatial knowledge in any context.

The result can provide solutions wherever conceptual knowledge references are involved. The methodologies and implementations make sure that powerful sets of unique attributes and features are available. The number of possible use cases is practically unlimited. The case studies showed that a wide range of application scenarios can benefit from the principles of superordinate knowledge and considering conceptual knowledge as complementary means for consistently documenting and handling knowledge. The passages in the following section refer to discussions and details for an excerpt of successful implementations.

VII. Evaluation from implementation cases

Many years of research and practical solution developments contributed to creating a comprehensive subset of conceptual knowledge, which is the fundament deployed for general practical solutions, e.g., with geo-spatial applications and with geo-data knowledge mining and processing.

TABLE I. COMPREHENSIVE SUBSET OF RESULTING CONCEPTUAL KNOWLEDGE REFERENCE DIVISIONS FOR GEO-SPATIAL APPLICATION SCENARIOS, PRACTICALLY USED MAIN CLASSIFICATION REFERENCES, UNIVERSAL DECIMAL CLASSIFICATION SAMPLES (UDC, ENGLISH; UDCC [17]; CC [18]).

CONCEPTUAL KNOWLEDGE REFERENCES FOR GEO-SPATIAL SCENARIOS			
Code / Sign Ref.	*Verbal Description (EN)*	*Code / Sign Ref.*	*Verbal Description (EN)*
Common Auxiliary Signs			
+	Coordination. Addition (plus sign).	[]	Subgrouping (square brackets).
/	Consecutive extension (oblique stroke sign).	*	Introduces non-UDC notation (asterisk).
:	Simple relation (colon sign).	A/Z	Direct alphabetical specification.
::	Order-fixing (double colon sign).	,	[Reference listing, itemisation]
Auxiliary Tables			
UDC:=...	Common auxiliaries of language.	UDC:(=...)	Common auxiliaries of human ancestry, ethnic
UDC:(0...)	Common auxiliaries of form.		grouping and nationality.
UDC:(1/9)	Common auxiliaries of place.	UDC:-0...	Common auxiliaries of general characteristics:
UDC:"..."	Common auxiliaries of time.		Properties, Materials, Relations/Processes and Persons.
Place and Space			
UDC:(1/9)	Common auxiliaries of place.	UDC:(20)	Ecosphere
UDC:(1)	Place and space in general. Localization. Orientation	UDC:(21)	Surface of the Earth in general.
UDC:(100)	Universal as to place. International. All countries in general		Land areas in particular.
UDC:(1-0/-9)	Special auxiliary subdivision for boundaries and		Natural zones and regions
	spatial forms of various kinds	UDC:(23)	Above sea level. Surface relief. Above ground
UDC:(1-0)	Zones		generally. Mountains
UDC:(1-1)	Orientation. Points of the compass. Relative position	UDC:(24)	Below sea level. Underground. Subterranean
UDC:(1-2)	Lowest administrative units. Localities	UDC:(25)	Natural flat ground (at, above or below sea level). The
UDC:(1-5)	Dependent or semi-dependent territories		ground in its natural condition, cultivated or inhabited
UDC:(1-6)	States or groupings of states from various points of view	UDC:(26)	Oceans, seas and interconnections
UDC:(1-7)	Places and areas according to privacy, publicness and	UDC:(28)	Inland waters
	other special features	UDC:(29)	The world according to physiographic features
UDC:(1-8)	Location. Source. Transit. Destination	UDC:(3/9)	Individual places of the ancient and modern world
UDC:(1-9)	Regionalization according to specialized points of view	UDC:(3)	Places of the ancient and mediaeval world
UDC:(2)	Physiographic designation	UDC:(4/9)	Countries and places of the modern world
Main Tables			
UDC:0	Science and Knowledge. Organization. Computer Science.	UDC:5	Mathematics. Natural Sciences
	Information. Documentation. Librarianship. Institutions. Publications	UDC:6	Applied Sciences. Medicine, Technology
UDC:1	Philosophy. Psychology	UDC:7	The Arts. Entertainment. Sport
UDC:2	Religion. Theology	UDC:8	Linguistics. Literature
UDC:3	Social Sciences	UDC:9	Geography. Biography. History
Science, Knowledge, Organisation			
UDC:001	Science and knowledge in general. Organization of intellectual work	UDC:007	Activity and organizing. Communication and control
UDC:002	Documentation. Books. Writings. Authorship		theory generally (cybernetics). 'Human engineering'
UDC:003	Writing systems and scripts	UDC:01	Bibliography and bibliographies. Catalogues
UDC:004	Computer science and technology. Computing. Data processing	UDC:02	Librarianship
UDC:004.4	Software	UDC:030	General reference works (as subject)
UDC:004.6	Computer data	UDC:050	Serial publications, periodicals (as subject)
UDC:004.7	Computer communication. Computer networks	UDC:06	Organizations of a general nature
UDC:004.8	Artificial intelligence	UDC:061	Organizations and other types of cooperation
UDC:005	Management	UDC:069	Museums. Permanent exhibitions
UDC:005.94	Knowledge management	UDC:070	Newspapers (as subject). The Press. Journalism
UDC:006	Standardization of products, operations, weights, measures and time	UDC:08	Polygraphies. Collective works
UDC:008	Civilization. Culture. Progress	UDC:09	Manuscripts. Rare and remarkable works
Geo-spatial Focus Divisions From Main Tables			
UDC:51	Mathematics	UDC:550.3	Geophysics
UDC:528	Geodesy. Surveying. Photogrammetry. Remote sensing. Cartography	UDC:550.7	Geobiology. Geological actions of organisms
UDC:528.2	Figure of the Earth. Earth measurement. Mathematical	UDC:550.8	Applied geology and geophysics. Geological
	geodesy. Physical geodesy. Astronomical geodesy		prospecting and exploration. Interpretation of results
UDC:528.3	Geodetic surveying	UDC:551	General geology. Meteorology. Climatology.
UDC:528.4	Field surveying. Land surveying. Cadastral survey.		Historical geology. Stratigraphy. Palaeogeography
	Topography. Engineering survey. Special fields of surveying	UDC:551.8	Palaeogeography
UDC:528.7	Photogrammetry: aerial, terrestrial	UDC:778	Special applications and techniques of photography
UDC:528.8	Remote sensing	UDC:91	Geography. Exploration of the Earth and of
UDC:528.9	Cartography. Mapping (textual documents)		individual countries. Travel. Regional geography
UDC:528.94	Thematic cartography. Topical cartography		(systematic geography). Theoretical geography
UDC:53	Physics	UDC:912	Nonliterary, nontextual representations of a region
UDC:55	Earth Sciences. Geological sciences	UDC:913	Regional geography

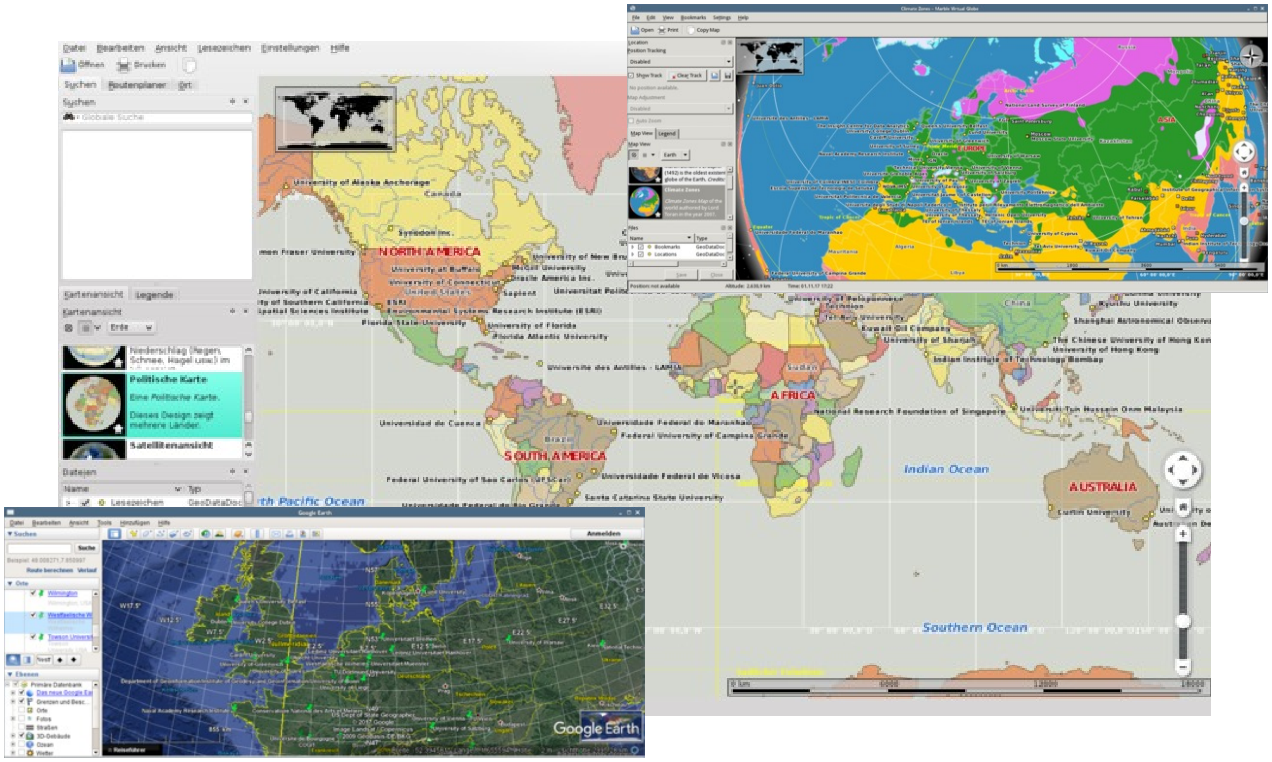

Figure 10. Collage of different implementation cases based on the resulting conceptual knowledge (Table I) from this research: Knowledge mapping, integration, mining; the samples illustrate context creation and dynamical visualisation. For technical details please see the references for the case studies given in the text.

The conceptual knowledge framework employed here, especially UDC, has passed the test of time and is so mature and used in so many scenarios that the ongoing knowledge development itself is iterating with its application.

The solution showed to fulfill all the major significant criteria, especially:

- The conceptual knowledge references (e.g., UDC) and components of the Knowledge Resources fully support for universal knowledge.
- These references and components of the Knowledge Resources fully support multi-disciplinary solutions, integrating facetted universal knowledge. All the components are multi-lingual. The conceptual knowledge references currently support about fifty languages.
- All the components, including the conceptual knowledge references allow sustainable, long-term usable edition framework, which is a base for consistent, extendable solutions on all components.

The solution allows all the consequent advanced features, which are directly linked to knowledge and documentation.

The previously unpublished results of practical conceptual knowledge are first presented with the research cited in this paper (Table I). The following case studies are based on these results and present small but illustrative excerpts (Figure 10) in form of a cross-section of conducted research and development, of Knowledge Resources, algorithms, intelligent workflows, and implementations.

Here, for example, a knowledge mining process employing knowledge objects based on the referred conceptual knowledge can use all the width and depth of knowledge behind the comprehensive subset to automatically or semi-automatically create new context and visualisation for a data set containing non-georeferenced text entities (affiliations in floating text), e.g., geographical, political, and climate zone context.

Besides the knowledge fundament and framework being focus of this research paper, the references in the next passages contain further details for the practical case studies, the implemented methods and the technologies, which were used for the different case studies.

- *Knowledge integration* allows to create new views and insights by computing Spatial Cogwheel modules [32].
- *Knowledge mining:* Creating Knowledge Resources and employing classification and concordances can provide a base for advanced knowledge discovery and computational solutions [16]. The integration of Knowledge Resources and advanced association processing can be beneficial in many disciplines as it provides multi-disciplinary and multi-lingual support [33].
  Methods like the Content Factor can be used for advanced knowledge processing [34]. The integration of appropriate methods can be used for further advancing the Knowledge Resources, as well as the mining processes [35].

- *The methodology of knowledge mapping* allows to create flexible methods in order to handle spatial representations and knowledge mining by creating a multi-dimensional context for arbitrary objects and entities [14].
- *Dynamical visualisation:* The methodology can be used for enabling knowledge based methods for computation and computational and dynamical visualisation [36].
- *Association and phonetic features:* The methodology supports phonetic association and mining methods [37].
- *Verbal description:* The employment of implemented methods can be supported and make use of multi-lingual verbal descriptions and concordances [38] as the conceptual knowledge is consistently available in 50 languages, providing millions of basic conceptual knowledge references.

VIII. Conclusion

This paper discussed the practice of formalised conceptual knowledge complements created with multi-disciplinary collections, containers, and referenced resources and presented different types of multi-disciplinary Knowledge Resources.

This paper presented a complements of formalised conceptual knowledge and a representative compilation of components from successful complex implementation scenarios. All such components are under creation and development for several decades, which have shown that the creation and development of multi-disciplinary Knowledge Resources is an essential long-term value.

With this research, a comprehensive subset of conceptual knowledge reference divisions was created, further developed, and finally compiled from the practical application case studies, which have been conducted and further developed over the last decades. This research achieved to create a comprehensive tool base of conceptual knowledge in geo-spatial application scenarios for all kinds of multi-disciplinary knowledge context in any media. The implemented superordinate knowledge based solution fulfills all the required criteria as was presented and discussed in this paper.

The result was employed to successfully implement a wide range of different geo-spatial cases.

Based on the presented research and practiced during extensive creation and development of complementary knowledge resources, a comprehensive subset of references to conceptual knowledge, allowing geo-spatially dominated facetted knowledge, was created, further developed, and finally compiled from the application case studies, which have been conducted over the last three decades. Knowledge based fundaments, e.g., those built on UDC, showed to have a very high impact on knowledge creation and mining in theory and practice, not only for spatial knowledge.

The knowledge approach proved to be a fundamental "enabler" and contributed significantly to many solutions. Covering a coherent system of knowledge provides a holistic and consistent environment for any scenario, which is supported by excellent features for facetted knowledge. The referenced conceptual knowledge itself is consistent due to its development and publication via editions. Implementations support fully multi-disciplinary context and multi-lingual instances for many languages. Solutions are extensible to integrate and fit special purposes. The methodology is data-centric and scalable for width and depth of knowledge as well as for infrastructure requirements. All the cases so far implementing the presented solution provided seamless integration with common geo-spatial practices and showed excellent sustainability, knowledge coverage, long-term characteristics, and scalability. In review of these results, all major institutions, e.g., libraries focussing on information science and research data management, are using and developing conceptual knowledge with their core tasks, which opens up a wide range of excellent knowledge sources, which can be considered high value resources. Moreover, such Knowledge Resources are complementary, independent of the fact that they can incorporate different methods and approaches, e.g., thesauri, semantic frameworks, ontologies, and phonetic interfaces for the content they handle.

Future research on theory and practice will concentrate on further developing the spectrum of references and creating knowledge reference based solutions for scenarios and disciplines. In addition, the creation and further development of knowledge resources is a multi-disciplinary long-term task.

Acknowledgements

We are grateful to the "Knowledge in Motion" (KiM) long-term project, Unabhängiges Deutsches Institut für Multidisziplinäre Forschung (DIMF), for partially funding this research, implementation, case studies, and publication under grants D2016F5P04648 and D2018F6P04938 and to its senior scientific members and members of the permanent commission of the science council, and the board of trustees, especially to Dr. Friedrich Hülsmann, Gottfried Wilhelm Leibniz Bibliothek (GWLB) Hannover, to Dipl.-Biol. Birgit Gersbeck-Schierholz, Leibniz Universität Hannover, to Dipl.-Ing. Martin Hofmeister, Hannover, and to Olaf Lau, Hannover, Germany, for collaboration, practical multi-disciplinary case studies, and the analysis of advanced concepts. We are grateful to Dipl.-Ing. Hans-Günther Müller, Cray, Germany, for his excellent contributions and assistance providing practical private cloud and storage solutions. We are grateful to all national and international partners in the Geo Exploration and Information cooperations for their constructive and trans-disciplinary support. We are grateful to the Science and High Performance Supercomputing Centre (SHPSC) for long-term support. / DIMF-PIID-DF98_007.

References

[1] C.-P. Rückemann, "Superordinate Knowledge Based Comprehensive Subset of Conceptual Knowledge for Practical Geo-spatial Application Scenarios," in Proceedings of The Eleventh International Conference on Advanced Geographic Information Systems, Applications, and Services (GEOProcessing 2019), February 24 – 28, 2019, Athens, Greece. XPS Press, Wilmington, Delaware, USA, 2019, pp. 52–58, ISSN: 2308-393X, ISBN: 978-1-61208-687-3, URL: http://www.thinkmind.org/index.php?view=article&articleid=geoprocessing_2019_3_30_30039 [accessed: 2019-07-07].

[2] C.-P. Rückemann, Sustainable Knowledge and Resources Management for Environmental Information and Computation. Business Expert Press, Manhattan, New York, USA, Mar. 2018, Chapter 3, pp. 45–88, in: Huong Ha (ed.), Climate Change Management: Special Topics in the Context of Asia, ISBN: 978-1-94784-327-1 (paperback), ISBN: 978-1-94784-328-8 (e-book), in: Robert Sroufe (ed.), Business Expert Press Environmental and Social Sustainability for Business Advantage Collection, ISSN: 2327-333X (collection, print).

[3] "ISO 14000 - Environmental management," 2019, URL: http://www.iso.org/iso/iso14000 [accessed: 2019-05-02].

[4] C.-P. Rückemann, "Superordinate Knowledge Based Comprehensive Subset of Conceptual Knowledge for Practical Mathematical-Computational Scenarios," in The Ninth Symposium on Advanced Computation and Information in Natural and Applied Sciences, Proceedings of The 17th International Conference of Numerical Analysis and Applied Mathematics (ICNAAM), September 23–28, 2019, Rhodes, Greece, Proceedings of the American Institute of Physics (AIP), no. 1. AIP Press, American Institute of Physics, Melville, New York, USA, Oct. 2020, ISSN: 0094-243X, (to appear).

[5] Aristotle, Nicomachean Ethics, Volume 1, 2009, Project Gutenberg, eBook, EBook-No.: 28626, Release Date: April 27, 2009, Digitised Version of the Original Publication, Produced by Sophia Canoni, Book provided by Iason Konstantinidis, Translator: Kyriakos Zambas, URL: http://www.gutenberg.org/ebooks/12699 [accessed: 2019-07-07].

[6] Aristotle, The Ethics of Aristotle, 2005, Project Gutenberg, eBook, EBook-No.: 8438, Rel. Date: Jul., 2005, Digit. Vers. of the Orig. Publ., Produced by Ted Garvin, David Widger, and the DP Team, Edition 10, URL: http://www.gutenberg.org/ebooks/8438 [accessed: 2019-07-07].

[7] L. W. Anderson and D. R. Krathwohl, Eds., A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives. Allyn & Bacon, Boston, MA (Pearson Education Group), USA, 2001, ISBN: 978-0801319037.

[8] C.-P. Rückemann, F. Hülsmann, B. Gersbeck-Schierholz, P. Skurowski, and M. Staniszewski, Knowledge and Computing. Post-Summit Results, Delegates' Summit: Best Practice and Definitions of Knowledge and Computing, Sept. 23, 2015, The Fifth Symp. on Adv. Comp. and Inf. in Natural and Applied Sciences (SACINAS), The 13th Int. Conf. of Num. Analysis and Appl. Math. (ICNAAM), Sept. 23–29, 2015, Rhodes, Greece, 2015, DOI: 10.15488/3409, URL: https://doi.org/10.15488/3409 [accessed: 2019-07-07].

[9] Plato, Phaedo, 2008, (Written 360 B.C.E.), Translated by Benjamin Jowett, Provided by The Internet Classics Archive, URL: http://classics.mit.edu/Plato/phaedo.html [accessed: 2019-07-07].

[10] T. Gooley, How to Read Nature: Awaken Your Senses to the Outdoors You've Never Noticed. New York, N.Y.: Experiment, 2017, ISBN: 978-1-61519-429-2.

[11] J. Burroughs, Leaf and Tendril, 1908, Ch. 1, The Art of Seeing Things.

[12] C.-P. Rückemann, "Principles of Superordinate Knowledge: Separation of Methodology, Implementation, and Realisation," in The Eighth Symposium on Advanced Computation and Information in Natural and Applied Sciences, Proceedings of The 16th International Conference of Numerical Analysis and Applied Mathematics (ICNAAM), September 13–18, 2018, Rhodes, Greece, Proceedings of the American Institute of Physics (AIP), vol. 2116. AIP Press, American Institute of Physics, Melville, New York, USA, 2019, ISSN: 0094-243X, (to appear).

[13] C.-P. Rückemann and F. Hülsmann, "Significant Differences: Methodologies and Applications," "Significant Differences: Methodologies and Applications", KiMrise, Knowledge in Motion Meeting, November 27, 2017, Knowledge in Motion, Hannover, Germany, 2017.

[14] C.-P. Rückemann, "Methodology of Knowledge Mapping for Arbitrary Objects and Entities: Knowledge Mining and Spatial Representations – Objects in Multi-dimensional Context," in Proceedings of The Tenth International Conference on Advanced Geographic Information Systems, Applications, and Services (GEOProcessing 2018), March 25–29, 2018, Rome, Italy. XPS Press, Wilmington, Delaware, USA, 2018, pp. 40–45, ISSN: 2308-393X, ISBN: 978-1-61208-617-0, URL: http://www.thinkmind.org/index.php?view=article&articleid=geoprocessing_2018_3_20_30078 [accessed: 2019-07-07].

[15] Organisation for Economic Co-operation and Development (OECD), "OECD Principles and Guidelines for Access to Research Data from Public Funding," 2007, URL: https://www.oecd.org/sti/sci-tech/38500813.pdf [accessed: 2019-07-07].

[16] C.-P. Rückemann, "Advanced Knowledge Discovery and Computing based on Knowledge Resources, Concordances, and Classification," International Journal on Advances in Intelligent Systems, vol. 9, no. 1&2, 2016, pp. 27–40, ISSN: 1942-2679, URL: http://www.thinkmind.org/index.php?view=article&articleid=intsys_v9_n12_2016_3/ [accessed: 2019-07-07].

[17] "Multilingual Universal Decimal Classification Summary," 2012, UDC Consortium, 2012, Web resource, v. 1.1. The Hague: UDC Consortium (UDCC Publication No. 088), URL: http://www.udcc.org/udcsummary/php/index.php [accessed: 2019-07-07].

[18] "Creative Commons Attribution Share Alike 3.0 license," 2012, URL: http://creativecommons.org/licenses/by-sa/3.0/ [accessed: 2019-07-07], (first release 2009, subsequent update 2012).

[19] F. Hülsmann and C.-P. Rückemann, "Symbolism and Meaning and Their Significance in Information Science," KiM Summit, February 20, 2018, Knowledge in Motion, Hannover, Germany, 2019.

[20] B. Gersbeck-Schierholz, "Art and Symbolism: The Sistine Chapel," KiM On-site Summit, Knowledge in Motion, March 27, 2018, On-site Summit Meeting, "Unabhängiges Deutsches Institut für Multidisziplinäre Forschung (DIMF)", Rome, Italy, 2018.

[21] B. Gersbeck-Schierholz and C.-P. Rückemann, "To See and Not to See," KiM On-site Summit, Knowledge in Motion, July 26, 2018, On-site Summit Meeting, "Unabhängiges Deutsches Institut für Multidisziplinäre Forschung (DIMF)", Museu Nacional d'Art de Catalunya, Barcelona, Spain, 2018.

[22] "UDC, Common Auxiliary Signs," 2019, Universal Decimal Classification (UDC), URL: https://udcdata.info/078885 [accessed: 2019-07-07].

[23] "UDC Summary Linked Data, Main Tables," 2019, Universal Decimal Classification (UDC), URL: https://udcdata.info/078887 [accessed: 2019-07-07].

[24] "UDC 0: Science and knowledge. Organization. Computer science. Information. Documentation. Librarianship. Institution. Publications," 2019, Universal Decimal Classification (UDC), URL: http://udcdata.info/13358 [accessed: 2019-07-07].

[25] "UDC (1/9): Common auxiliaries of place," 2019, Universal Decimal Classification (UDC), URL: http://udcdata.info/001951 [accessed: 2019-07-07].

[26] "UDC 528: Geodesy. Surveying. Photogrammetry. Remote sensing. Cartography," 2019, Universal Decimal Classification (UDC), URL: http://udcdata.info/027504 [accessed: 2019-07-07].

[27] "UDC 910: General questions. Geography as a science. Exploration. Travel," 2019, Universal Decimal Classification (UDC), URL: http://udcdata.info/068129 [accessed: 2019-07-07].

[28] "UDC 912: Nonliterary, nontextual representations of a region," 2019, Universal Decimal Classification (UDC), URL: http://udcdata.info/068183 [accessed: 2019-07-07].

[29] "UDC 913: Regional geography," 2019, Universal Decimal Classification (UDC), URL: http://udcdata.info/068186 [accessed: 2019-07-07].

[30] "UDC 94: General history," 2019, Universal Decimal Classification (UDC), URL: http://udcdata.info/068284 [accessed: 2019-07-07].

[31] N. T. Nikolitsis, "Archäologische Unterwasser-Expedition bei Rhodos, (English: Archaeological Underwater-Expedition at Rhodes)," Antike Welt, Zeitschrift für Archäologie und Kulturgeschichte, (English: Antique World, Magazine for Archaeology and Cultural History), 1981, 12. Jg., Heft 1, (English: 12th Year, Issue 1), pp. 45–58.

[32] C.-P. Rückemann, "Creating New Views and Insights by Computing Spatial Cogwheel Modules for Knowledge Integration," Int. Journ. on Adv. in Intell. Syst., vol. 10, no. 3&4, 2017, pp. 314–326, ISSN: 1942-2679, URL: http://www.thinkmind.org/index.php?view=article&articleid=intsys_v10_n34_2017_13/ [accessed: 2019-07-07].

[33] C.-P. Rückemann, "Integration of Knowledge Resources and Advanced Association Processing for Geosciences and Archaeology," Int. Jour. on Adv. in Systems and Measurements, vol. 9, no. 3&4, 2016, pp. 485–495, ISSN: 1942-261x, URL: http://www.thinkmind.org/index.php?view=article&articleid=sysmea_v9_n34_2016_22/ [accessed: 2019-07-07].

[34] C.-P. Rückemann, "Knowledge Processing and Advanced Application Scenarios With the Content Factor Method," International Journal on Advances in Intelligent Systems, vol. 9, no. 3&4, 2016, pp. 485–495, ISSN: 1942-2679, URL: http://www.thinkmind.org/index.php?view=article&articleid=intsys_v9_n34_2016_22/ [accessed: 2019-07-07].

[35] C.-P. Rückemann, "Progressive Advancement of Knowledge Resources and Mining: Integrating Content Factor and Comparative Analysis Methods for Dynamical Classification and Concordances," Int. Journal on Adv. in Systems and Measurements, vol. 11, no. 1&2, 2018, ISSN: 1942-261x, URL: http://www.thinkmind.org/index.php?view=article&articleid=sysmea_v11_n12_2018_5/ [accessed: 2019-07-07].

[36] C.-P. Rückemann, "Creating Knowledge-based Dynamical Visualisation and Computation," in Proc. of The Seventh International Conference on Advanced Geographic Information Systems, Applications, and Services (GEOProcessing 2015), February 22–27, 2015, Lisbon, Portugal. XPS Press, 2015, pp. 56–62, ISSN: 2308-393X, ISBN: 978-1-61208-383-4, URL: http://www.thinkmind.org/index.php?view=article&articleid=geoprocessing_2015_3_40_30063 [accessed: 2019-07-07].

[37] C.-P. Rückemann, "Archaeological and Geoscientific Objects used with Integrated Systems and Scientific Supercomputing Resources," Int. Jour. on Adv. in Systems and Measurements, vol. 6, no. 1&2, 2013, pp. 200–213, ISSN: 1942-261x, URL: http://www.thinkmind.org/download.php?articleid=sysmea_v6_n12_2013_15 [accessed: 2019-07-07].

[38] C.-P. Rückemann, "Methodology Enabling Knowledge Mining Computation Based on Conceptual Knowledge and Verbal Description," in The Seventh Symposium on Advanced Computation and Information in Natural and Applied Sciences (SACINAS), Proc. of The 15th Int. Conf. of Num. Analysis and Appl. Math. (ICNAAM), Sept. 25–30, 2017, Thessaloniki, Greece, AIP Conference Proceedings, Vol. 1728, no. 1. AIP Press, Melville, New York, USA, Jul. 2018, ISBN: 978-0-7354-1690-1 (Book), ISSN: 0094-243X, DOI: 10.1063/1.5043723.