Methodology of Chorological and Coherent Conceptual Knowledge Contextualisation: Approaches for Multi-disciplinary Contexts in Prehistory and Archaeology

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***Abstract*—This paper presents research on a new methodology of general chorological and coherent conceptual knowledge contextualisation across disciplines. The presented achievements and scenarios concentrate on new information science approaches for multi-disciplinary contexts in prehistory and archaeology, targeting the use of inherent aspects and creation of new insight, strategies, and perspectives. The new advanced approach can be applied to any type of knowledge, e.g., factual, conceptual, procedural, metacognitive, and structural. The integration of chorological knowledge includes integration of spatial and geospatial knowledge and features. Goal of this research are new facilities for coherent contextualisation in multi-disciplinary contexts. Here, we are focussing on coherent knowledge in contexts with prehistory and archaeology disciplines, natural sciences, and advanced geoscientific information systems. The solution also integrates knowledge from satellite data and soil diversity and respective properties. The knowledge approach allows a multi-directional utilisation of coherent conceptual knowledge. Future research concentrates on further continuing the development of components and application in multi-disciplinary scenarios of prehistory and archaeology.**

Keywords–Prehistory; Natural Sciences; Chorology; Information Science; Contextualisation; Coherent Conceptual Knowledge.

I. Introduction

These days, mostly all Geographic Information Systems and even more advanced and more complex Geoscientific Information Systems (GIS) are –by themselves– not yet taking multi-disciplinary coherent knowledge and contexts into consideration. From scientific point of view, it is a questionable approach to think of and practice a distinct discipline while considering any other required scientific discipline being auxiliary, which, for further simplification, may even be reduced to ‘data delivery’, ‘technical’, and ‘procedural’ contributions.

Multi-disciplinary scenarios often require to consider a wide range of contexts with disciplines put to their level. It is the coherent knowledge of contexts, which is most relevant for new insight. Therefore, contextualisation should not be done without considering multi-disciplinary coherency and expert views from different disciplines put on a par with respective further scientific collaboration and support.

Goal of this research are new information science facilities for a coherent conceptual contextualisation. The result of this research is a new methodology of general chorological and coherent conceptual knowledge contextualisation. The new advanced approach enables a systematical, coherent contextualisation and can be applied with knowledge complements, e.g., factual, conceptual, procedural, metacognitive, and structural. The approach is knowledge-centric, in a way “knowledge-driven” but explicitly not “development-procedure-driven” or “software-driven”. From knowledge complements’ point of view, chorology is for place what chronology is for time. The integration of chorological knowledge includes integration of spatial and geospatial knowledge and features. Here, we are focussing on scenarios of coherent multi-disciplinary knowledge in context with prehistory and archaeology, natural sciences, and advanced geoscientific information system components. The solution also integrates knowledge from satellite data and soil diversity with respective properties. Contexts in prehistory are special in a way that there are no direct historical sources and respectively no literary reference and documentation. Contextualisation is therefore a main intrinsic task in prehistory and protohistory. An approach has to conform with information science fundaments and universal knowledge and has to enable an integration of the required components from methodologies to realisations for knowledge representations of realia and abstract contexts [1] while many facets of knowledge, including prehistory, need to be continuously acquired and reviewed [2]. There is no published approach known, which can be reasonably compared with the implemented and presented method. Therefore, there was a strong need for an advanced methodology to contextualise knowledge, e.g., from practically available knowledge resources. This paper presents the methodological fundaments for a chorological and coherent multi-disciplinary contextualisation. The potential for finding and integrating multi-disciplinary inherent aspects and creation of new insight, strategies, and perspectives by development of components employing coherent conceptual knowledge has been a major motivation.

The rest of this paper is organised as follows. Section II presents the method of component integration and the relevant components in ongoing development. Section III shows the solution, results of practical implementation and realisation, which have been realised for prehistory and archaeology contexts. Section IV demonstrates and discusses the resulting coherent conceptual knowledge integration. Section V summarises lessons learned, conclusions, and future work.

II. Component integration and method

Commonly used tools are not aware of features for contextualisation from multi-disciplinary components. Therefore, advanced individual workflows need proper preparation of components and workflow procedures. Preparation requires methods for deployment of respective knowledge characteristics and properties. Further, any workflow should be created being aware of the individuality of these characteristics.

Many aspects of knowledge, including meaning, can be described using knowledge complements supporting a modern definition of knowledge and subsequent component instrumentation [3] [4], e.g., considering factual, conceptual, procedural, metacognitive, and structural knowledge. Especially, conceptual knowledge can relate to any of factual, conceptual, procedural, and structural knowledge. Knowledge complements are a means of understanding and targeting new insight, e.g., enabling advanced contextualisation, integration, analysis, synthesis, innovation, prospection, and documentation. The approach can be summarised based on the methodological fundaments.

- Selection and development of a coherent, multi-disciplinary reference implementation. Knowledge complements are addressing reference implementations.
- Multi-disciplinary knowledge resources and integrated components are realised with knowledge-centric focus.
- Contextualisation employing knowledge complements.
- Analysis, synthesis, documentation can employ reference implementations for new insight and development.

An approach to the multi-disciplinary nature of this research requires significant developments of coherently integrationable, fundamental context components especially

- multi-disciplinary contexts of prehistory and archaeology and respective resources,
- chorological contexts, e.g.,
- homogeneously consistent high resolution Digital Elevation Model (DEM) for land and sea bottom, and
- natural sciences Knowledge Resources (KR), e.g., soil classification resources, standardised soil reference systems, and parameters.

The following passages give a compact overview of major component implementations and development integrated with this research. A more detailed, comprehensive discussion and examples regarding the fundaments are available with the research on methodology, contextualisation, and conceptual knowledge. Relevant pre-existing and ongoing component developments addressing knowledge with multi-disciplinary KR have been summarised [5].

a) Conceptual knowledge frameworks: A main reference implementation developed and used in practice with ongoing long-term research and applied for KR is the prehistory-protohistory and archaeology Conceptual Knowledge Reference Implementation (CKRI), including multi-disciplinary contexts of natural sciences and humanities [6].

b) Conceptual knowledge base: Conceptual knowledge base is The Universal Decimal Classification (UDC) [7], a general plan for knowledge classification, providing an analytico-synthetic and facetted classification, designed for subject description and indexing of content of information resources irrespective of the carrier, form, format, and language. UDC-based references in this publication are taken from the multilingual UDC summary [7] released by the UDC Consortium under a Creative Commons license [8].

c) Integration of scientific reference frameworks: The integration includes relevant scientific practices, frameworks, and standards from disciplines and contexts. Geosciences and soil science are continuously delivering updated state of the art research and insight, including geodiversity and standardisation [9] [10] as required for contextualisation. A practical reference implementation for coherent contextualisation of prehistory-protohistory and archaeology conceptual knowledge [6] is currently in development within a long-term project accompanying this research.

d) Formalisation: All integration components, for all disciplines, require an explicit and continuous formalisation [11] process in order to conform with the information science principles according to the practices in the disciplines.

e) Methodologies and workflows integration: Methodologies for creating and utilising methods include model processing, remote sensing, spatial mapping, high information densities, and visualisation. The respective contextualisation of prehistoric scenarios should each be done under individual prehistoric conditions, especially supported by standard algorithms [12], multi-dimensional criteria, spatial operations, interpolation geodesic computation [13], triangulation [14], gradient computation [15], and projection [16].

f) Prehistory Knowledge Resources: In order to overcome basic shortcomings of public ‘data collections’ the objects, entities, and respective conceptual knowledge references’ excerpts and examples are taken from The Prehistory and Archaeology Knowledge Archive (PAKA). PAKA has been in continuous development for more than three decades [17] and is released by DIMF [18].

g) Natural Sciences Knowledge Resources: Several coherent systems of major natural sciences’ context object groups from KR realisations have been implemented [5] [7] [19].

h) Inherent representation groups: The methodology can consider a wide range of representation groups for major disciplines and context object groups regarding their inherent representation and common utilisation, e.g., points, polygons, lines, Digital Elevation Model (DEM) representations, z-value representations, distance representations, area representations, raster, vector, binary, and non-binary data.

i) Scientific context parametrisation: Scientific context parametrisation of prehistoric targets can use the overall insights, e.g., from geoscientific disciplines [20] [21]. A relevant example is contextualisation with palaeolandscapes [22].

j) Structures and symbolic representation standards: The deployment of long-term universal structure and data standards is essential. Relevant examples of sustainable implementations are NetCDF [23] based standards, including advanced features, hybrid structure integration, and parallel computing support (PnetCDF) and generic multi-dimensional table data, universal source and text based structure and code representations.

Results of the practical implementations and realisations are presented in the following sections.

III. Resulting Implementation and Realisation

A means of choice in order to achieve overall efficient realisations even for complex scenarios, integrating arbitrary knowledge, is to use the principles of Superordinate Knowledge. The core assembly elements of Superordinate Knowledge are methodology, implementation, and realisation [24].

In the following solution, scenario targets are contexts of prehistoric cemeteries and burials at the North Sea coast, in North-Rhine Westphalia, Lower Saxony, and The Netherlands. Integration targets are natural sciences and speleological contexts, caves and cave systems in North-Rhine Westphalia, Lower Saxony, and The Netherlands, soil diversity, and overall integration with chorological, symbolical, spatial context representations, e.g., place, spatial planning, auxiliary subdivisions for boundaries and spatial forms and administrative units.

A. Coherent conceptual knowledge implementation

We can select relevant references from the implemented prehistory-protohistory and archaeology CKRI [6]. The methodology allows to address any other references on a coherent information science knowledge base, e.g., geoscientific knowledge from natural sciences KR components. Further, the reference implementation enables to address chorology on the coherent knowledge base. Universally consistent conceptual knowledge is based on UDC references for demonstration, spanning the main tables [25] shown in Table I.

TABLE I. COHERENT CONCEPTUAL KNOWLEDGE DEPLOYED FOR CONTEXTUALISATION, SELECTED UDC CODE REFERENCES (EXCERPT).

Code / Sign Ref.	*Verbal Description (EN)*
UDC:0	Science and Knowledge. Organization. Computer Science. Information. Documentation. Librarianship. Institutions. Publications
UDC:004	*Computer science and technology. Computing.*
UDC:1	Philosophy. Psychology
UDC:2	*Religion. Theology*
UDC:3	Social Sciences
UDC:5	Mathematics. Natural Sciences
UDC:52	*Astronomy. Astrophysics. Space research. Geodesy*
UDC:53	Physics
UDC:539	Physical nature of matter
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:551.44	*Speleology. Caves. Fissures. Underground waters*
UDC:551.46	Physical oceanography. Submarine topography. Ocean floor
UDC:551.7	Historical geology. Stratigraphy
UDC:551.8	Palaeogeography
UDC:56	Palaeontology
UDC:6	Applied Sciences. Medicine, Technology
UDC:63	Agriculture and related sciences and techniques. Forestry. Farming. Wildlife exploitation
UDC:631.4	*Soil science. Pedology. Soil research*
UDC:7	The Arts. Entertainment. Sport
UDC:8	Linguistics. Literature
UDC:9	Geography. Biography. History
UDC:902	Archaeology
UDC:903	*Prehistory. Prehistoric remains, artefacts, antiquities*
UDC:904	Cultural remains of historical times
UDC (1/9)	Common auxiliaries of place
UDC:(1)	Place and space in general. Localization. Orientation
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:(3/9)	Individual places of the ancient and modern world
UDC:(3)	Places of the ancient and mediaeval world
UDC:(4/9)	Countries and places of the modern world
UDC:(4)	*Europe*
UDC:"..."	Common auxiliaries of time.
UDC:"6"	Geological, archaeological and cultural time divisions
UDC:"62"	*Cenozoic (Cainozoic). Neozoic (70 MYBP - present)*

For this research, major references from both main and auxiliary tables are highlighted in italics with bluish colour.

B. Multi-disciplinary views: Prehistory and archaeology

Table II shows an excerpt of UDC:903. . . :2 ritual/burial object and subgroup examples, and conceptual view groups [7] for prehistory and protohistory (PAKA, [17] [18]).

TABLE II. PREHISTORY AND PROTOHISTORY RITUAL/BURIAL OBJECT AND SUBGROUP EXAMPLES, AND CONCEPTUAL VIEW GROUPS [7] (EXCERPT).

Major Object Group	*Selected Objects*	*Conceptual View Group*
Ritual places, burials	yes	UDC:903. . . :2
Cemetery	–	UDC:903. . . :2
Barrow	–	UDC:903. . . :2
round	–	UDC:903. . . :2
long	–	UDC:903. . . :2
Cist	–	UDC:903. . . :2
Dolmen	–	UDC:903. . . :2
Tomb	–	UDC:903. . . :2
chamber	–	UDC:903. . . :2
court	–	UDC:903. . . :2
portal	–	UDC:903. . . :2
rock cut	–	UDC:903. . . :2
wedge	–	UDC:903. . . :2
Pithos burial	–	UDC:903. . . :2
Cave	–	UDC:903. . . :2
Body finding	–	UDC:903. . . :2
Urn	–	UDC:903. . . :2
. . .	–	UDC:903. . . :2

For this illustrative object scenario, the excerpt does not show individual micro-groups. Besides different distributions and different origins, object context can be referred, e.g., artificial origin and natural origins as well as relevant object properties, materials, and soil contexts can be considered.

C. Resulting realisation components: Soil diversity

A suitable UDC:631.4. . . base soil reference system for prehistory and archaeology has been compiled along with this research. The results are available in Table III.

TABLE III. COMPILATION OF CONCEPTUAL REFERENCE SYSTEM (UDC:631.4. . .), IMPLEMENTED AND REALISED WRB STANDARD SOIL TYPE REFERENCE GROUPS AND SOIL TYPE SPECIFICATIONS.

Soil type Reference group	*Soil type specification Name in WRB 2006 / WRB 1998*
Acrisol	Haplic / Ferric, Gleyic, Haplic, Humic, Plinthic
Alisol	Plinthic
Albeluvisol	Haplic / Endoeutric, Gleyic, Haplic, Histic, Stagnic, Umbric
Andosol	Aluandic / Dystric, Humic, Umbric, Mollic, Vitric
Anthrosol	Anthrosol, Plaggic
Arenosol	Albic, Haplic, Protic
Calcisol	Aridic
Chernozem	Calcic, Haplic, Gleyic, Haplic, Luvic
Cambisol	Haplic / Calcaric, Haplic / Chromic, Haplic / Dystric, Haplic / Eutric, Gleyic, Haplic, Mollic, Vertic
Fluvisol	Haplic / Calcaric, Haplic / Dystric, Haplic / Eutric, Gleyic, Haplic, Histic, Mollic, Salic, Thionic
Gleysol	Haplic / Calcaric, Haplic / Dystric, Haplic / Eutric, Haplic / Haplic, Histic, Humic, Mollic, Thionic
Gypsisol	Haplic / Aridic
Histosol	Histosol, Hemic / Dystric, Hemic / Eutric, – / Fibric, – / Gelic, – / Sapric
Kastanozem	Calcic, Haplic, Luvic
Leptosol	Haplic / Calcaric, Haplic / Dystric, Haplic / Eutric, Haplic / Haplic, Haplic / Humic, Rendzic, Lithic
Luvisol	Albic, Haplic / Arenic, Calcic, Haplic / Chromic, Haplic / Dystric, Haplic / Ferric, Gleyic, Haplic, Vertic
Phaeozem	– / Albic, Haplic / Calcaric, Gleyic, Haplic, Luvic, Haplic / Sodic
Planosol	Haplic / Dystric, Haplic / Eutric, Haplic
Podzol	Haplic / Carbic, Haplic / Entic, Gleyic, Haplic, Leptic, Placic, Haplic / Rustic, Umbric
Regosol	Haplic / Calcaric, Haplic / Dystric, Haplic / Eutric, Haplic
Solonchak	Gleyic, Haplic, Haplic / Takyric, Mollic
Solonetz	Gleyic, Haplic, Mollic
Umbrisol	Arenic, Gleyic
Vertisol	Haplic / Chromic, Haplic, Haplic / Pellic

For this research, the reference system is based on standard soil references and UDC, both enabling a systematic and coherent approach. Soil diversity groups are relevant for prehistorical and archaeological objects and contexts. Contextualised soil diversity groups are referenced in a consistent, standardised way. From this base compilation, a properties based reference system can be created for further contextualisation, parametrisation, and processing with the ongoing research on soil diversity for prehistory and archaeology. Associated information, e.g., on soil drainage, wetness, pH status, base saturation, chloride, subsoil organic material, and stiffness can be found as reference in the World Reference Base (WRB) for soil resources [26], [27] from the Food and Agriculture Organisation (FAO), United Nations. In this context, the conceptual references are referring to the respective categories, e.g., UDC:631.4. . .:903+“4. . .”.

D. Multi-disciplinary integration facets

Table IV shows the reference facets of a respective multi-disciplinary target contextualisation.

TABLE IV. REFERENCE FACETS OF A MULTI-DISCIPLINARY TARGET CONTEXTUALISATION, BASED ON CKRI, IMPLEMENTED AND REALISED USING UDC CODE REFERENCES (EXCERPT).

Code / Sign Ref.	*Verbal Description (EN)*
	Geography. Biography. History
UDC:903.. . .	Prehistory, prehistoric remains, artefacts, antiquities
. . .:2	referring to religion and rituals
. . .,“62. . .”	from Holocene
. . .,(4. . .DENW)	. . . in North-Rhine Westphalia, Germany
. . .,(4. . .DENI)	. . . in Lower Saxony, Germany
. . .,(4. . .NL)	. . . in The Netherlands
	Earth sciences, geological sciences
UDC:551.44	Speleology, caves, fissures, underground waters
	Applied sciences, agriculture in general
UDC:631.4	Soil research data
	Geodesy. Photogrammetry
UDC:52. . .,(23)	Remote sensing data, above sea level
UDC:52. . .,(24)	Remote sensing data, below sea level
	Contextualisation Place
UDC:(4)	Europe

The contextualisation uses coherent conceptual knowledge and refers to the chorological references for consequent knowledge integration and symbolic representation.

IV. RESULTING COHERENT KNOWLEDGE INTEGRATION

Figure 1 shows a generated, resulting coherent conceptual knowledge integration sketch for the realisation based on the KR. The sketch considers the major conceptual references for illustration. Detailed research can further detail on prehistoric object groups, characteristics, and properties, topographic properties, soil properties, and many more. Therefore, the conceptual sketch view can result in levels of arbitrary numbers of different integrations of complements and associated properties as resulting from the KR, which are discussed in the following. The result integrates required KR components based on coherent conceptual knowledge and systematical chorological knowledge for multi-disciplinary contexts, e.g., arbitrary group representations, classification based representations, and geospatial representations.

Knowledge objects and contexts are provided by The Prehistory and Archaeology Knowledge Archive (PAKA) [17] [18]. The multi-disciplinary coherent contextualisation employs the base of a new soil system reference development with soil types (UDC:631.4. . .) of WRB standard, reference contexts, especially for UDC:903.. . .:2,551.7+“628”.. . ., prehistorical, protohistorical time spans and artefacts related to religion and rituals, geology, especially stratigraphy and paleogeography, quaternary, especially late glacial and Holocene. The integrated natural sciences KR further provide information on caves in the respective region. Contextualisation is enabled by the Conceptual Knowledge Reference Implementation (CKRI), including multi-disciplinary contexts of natural sciences and humanities [6]. The conceptual knowledge base is The Universal Decimal Classification (UDC) [7].

In this illustration plain Digital Chart of the World (DCW) data are used [28]. The coastline database is the Global Self-consistent Hierarchical High-resolution Geography (GSHHG) [29] [30], which was mainly compiled from the World Vector Shorelines (WVS) [31], the CIA World Data Bank II (WDBII) [32], and the Atlas of the Cryosphere (AC).

An equal area projection (Eckert IV) is advised due to the type of discipline knowledge representation. The compilation uses the World Geodetic System (WGS). The symbolic representation of the contextualisation is done via LX Professional Scientific Content-Context-Suite (LX PSCC Suite) deploying the Generic Mapping Tools (GMT) [33] for visualisation.

Concrete details of knowledge complements and components have been provided [5]. All basic technical aspects can be created on that base for individual application scenarios. As illustrated, the solution is explicitly not a database concept and the goal is explicitly not just to link different multi-disciplinary concepts. The solution allows to create individual conceptual knowledge based algorithms and to integrate with new and available spatial and temporal processing algorithms. Basic components and functions are given in the references.

The presented integration approach for chorological and coherent contextualisation provides a solid base for multi-disciplinary contexts in prehistory and archaeology. The implemented system of components, continuously in development, integrates relevant and beneficial methodologies and properties, especially

- coherent conceptual knowledge views,
- multi-disciplinary contextualisation,
- application approaches for multi-disciplinary contexts in prehistory and archaeology,
- allows systematical chorological consideration of knowledge, e.g., arbitrary group representations, classification based representations, geospatial representations,
- further development and valorisation of resources,
- integration of multi-disciplinary resources,
- choice for homogeneity of components,
- deployment of systematical procedures,
- effective and efficient integration and analysis,
- automation of workflows and procedures, and
- provides multi-lingual conceptual knowledge support.

The methodological approach also allows the multi-directional utilisation: Conceptual knowledge and resulting integration, e.g., symbolic representation, on the one hand and integration results delivering references to conceptual knowledge and new integrated knowledge contexts on the other hand.

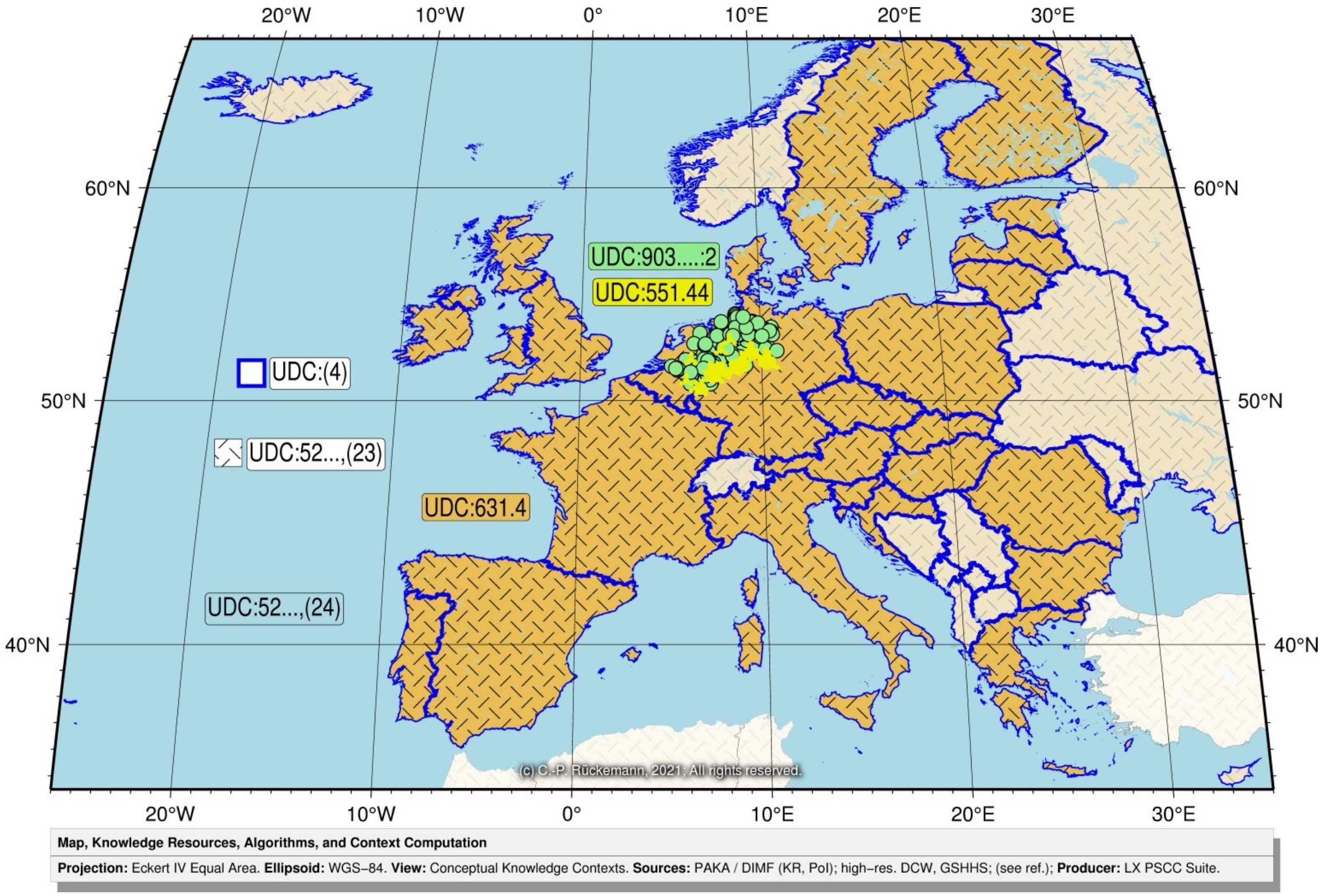

Figure 1. Resulting coherent conceptual knowledge integration sketch diagram showing knowledge resources for a prehistoric, natural sciences, and spatial contextualisation for excerpts of prehistoric cemeteries' and caves' distributions, remote sensing data, and soil properties with respective knowledge references.

As demonstrated with the integration for this research, besides coherency, general flexibility, robustness, and scalability, criteria for components employed with implementation and realisation should be evaluated carefully for being able to consider solid information science fundaments and knowledge centricity, beyond plain technical and proprietary features.

Resulting from the methodology, the realisation integrates a wide range of relevant selection criteria, e.g., in this scenario:

- Conceptual selection (esp. prehistory, cemetery; natural sciences, caves).
- Spatial, mathematical selection.
- Regional spatial selection.
- Topographic selection (esp. above sea level).
- Contextualised selection (esp. with availability of sufficient natural sciences, soil, and other context data).

V. Conclusion

The practical solution for implementation and realisation of the new knowledge-based methodology showed to enable coherent conceptual knowledge for contextualisation in prehistory, archaeology, and natural sciences. The more, the approach enables to integrate multi-disciplinary contexts by a consistent system (editions) and supports multi-lingualism. Multi-disciplinary scenarios can be considered in multi-fold ways, e.g., knowledge can be documented, analysed, integrated, and selected deploying conceptual knowledge. The methodological approach also allows a multi-directional utilisation. Any KR result can be considered starting point, intermediate result, and final result, depending on a defined task and workflow.

The general methodology provides flexibility for solid information science based methods and enables a wide range of benefits for scenarios and implementations, e.g., coherent multi-disciplinary and multi-lingual documentation and systematical knowledge based geo-spatial processing, aware of inherent knowledge spanning arbitrary disciplines. With that, geospatial scenarios are special cases of chorological contextualisation. Further recommendations from practical experiences with knowledge complements and component integration are:

- Add consistent and coherent conceptual knowledge to objects and entities of your resources and make workflows deploy conceptual knowledge.
- Choose multi-disciplinary resources with homogeneous properties, e.g., resolution and coverage.
- Use long-term standards.
- Practice scientific state-of-the-art parametrisation of respective knowledge, data, and algorithms.
- Create context dependent, suitable symbolic representations and individual methods.
- Proceed the knowledge-centric integration reasoned and levelheaded.

Future research concentrates on continuing development of components for detailed multi-disciplinary application scenarios in prehistory and archaeology and respective chorological and coherent conceptual knowledge contextualisation.

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