Towards a Component Reference Implementations Frame for Achieving Multi-disciplinary Coherent Conceptual and Chorological Contextualisation in Prehistory and Prehistoric Archaeology

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Abstract—**This paper presents contributions towards a new component reference implementations frame, which can be used with conceptual knowledge models. The extended research allows a general chorological and coherent conceptual knowledge contextualisation across disciplines. The frame will enable to coherently address multi-disciplinary knowledge by employing conceptual knowledge frameworks and component reference implementations. 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 is a new component reference implementations frame for multi-disciplinary coherent conceptual and chorological contextualisation. For the case scenarios, 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 continued development of components, analysis, and application in multi-disciplinary scenarios of prehistory and archaeology.**

***Keywords*–Reference Component Implementations Frame; Prehistory; Natural Sciences; Chorology; Contextualisation; Coherent Conceptual Knowledge.**

I. INTRODUCTION

This paper presents the new component reference implementations frame, which can be used with conceptual knowledge reference implementations. The extended research allows a general chorological and coherent conceptual knowledge contextualisation across disciplines. The frame enables to coherently address multi-disciplinary knowledge by employing conceptual knowledge frameworks and component reference implementations. This paper is an extended and updated presentation of the research based on the publication and presentation at the GEOProcessing 2021 conference in Nice, France [1].

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.

Many measurements and and contexts in prehistorical archaeology and natural sciences cannot be 'sensed' directly and require further endeavours. 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 is a new component reference implementations frame for multi-disciplinary coherent conceptual and chorological contextualisation, based For the case scenarios, we are focussing on coherent knowledge in contexts with prehistory and archaeology disciplines, natural sciences, and advanced geoscientific information systems.

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".

The rest of this paper is organised as follows. Section II presents the method of component integration. Section III illustrates the implementation and realisation scenario for prehistory's and archaeology's conceptual and chorological knowledge reference implementation contexts. Section IV discusses the coherent conceptual knowledge integration scenario case study. Section V delivers the new component reference implementation frame with major building blocks. Sections VI and VII discuss the state of the achieved results and summarise lessons learned, conclusions, and future work.

II. COMPONENT INTEGRATION AND METHOD

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 peculiar 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 [2] while many facets of knowledge, including prehistory, need to be continuously acquired and reviewed [3]. 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.

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 [4] [5], e.g., considering factual, conceptual, procedural, metacognitive, and structural knowledge. Especially, conceptual knowledge can relate to any of factual, conceptual, procedural, and structural knowledge. To a comparable extent, metacognitive 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.

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 [6] and discussed.

Further, major practical groups of component implementations and developments required and addressed for integration with this research are:

1) Conceptual knowledge frameworks.
2) Conceptual knowledge base.
3) Integration of scientific reference frameworks.
4) Formalisation.
5) Methodologies and workflows integration.
6) Prehistory Knowledge Resources.
7) Natural Sciences Knowledge Resources.
8) Inherent representation groups.
9) Scientific context parametrisation.
10) Structures and symbolic representation.

The following sections will present the implementation and realisation and integration scenarios and the new resulting component reference implementation frame.

The implementation and realisation scenario is based on the coherent conceptual knowledge reference implementations. The integration scenario employs these reference implementations and delivers the realisation of integration and symbolic representation and facilities for further analysis. General chorological and coherent conceptual aspects are in focus of realisations. The resulting component reference implementation frame delivers the practical integration frame of components for implementation and realisation and consistently includes available coherent conceptual knowledge reference implementations for this and future multi-disciplinary scenarios.

III. Implementation and realisation scenario

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 [7].

In the following example solutions, 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 reference implementation*

We can select relevant references from the implemented prehistory-protohistory and archaeology Conceptual Knowledge Reference Implementation (CKRI) [8] (E.0.4.4). 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 [9] 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 [10] (PAKA, [11] [12]), referenced according the prehistory-protohistory and archaeology CKRI (E.0.4.4).

TABLE II. CKRI: PREHISTORY AND PROTOHISTORY RITUAL/BURIAL OBJECT AND SUBGROUP EXAMPLES, AND VIEW GROUPS [10] (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

Regarding the conceptual properties, these example objects and objects groups represent knowledge facets rather than simple hierarchical references. Contextualisation based on conceptual knowledge can this way be employed in combinatory fashion and can address peculiarities by flexible means, e.g., by knowledge complements, symbolic representation, and conceptual knowledge views of chorology and chronology.

For this illustrative object scenario, the excerpt does not show individual micro-groups and individual differences. 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 and systematically contextualised.

C. Multi-disciplinary views: Soil diversity

A soil diversity CKRI development edition (E.0.6.2) was created based on WRB standard soil type reference groups and soil type specifications [13], [14], and a suitable UDC:631.4. . . base soil reference system for prehistory and archaeology, which has been compiled along with this research. The results are available in Table III.

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 [13], [14] from the Food and Agriculture Organisation (FAO), United Nations.

TABLE III. CKRI: SOIL DIVERSITY, BASED ON WRB STANDARD AND CONCEPTUAL REFERENCE SYSTEM (UDC:631.4. . .), (E.0.6.2).

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

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 (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

Reference facets of a multi-disciplinary target contextualisation are based on CKRI, implemented and realised using UDC code references. The contextualisation uses coherent conceptual knowledge and refers to the chorological references for consequent knowledge integration and symbolic representation.

IV. COHERENT KNOWLEDGE INTEGRATION SCENARIO

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) [11] [12]. 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 [8]. The conceptual knowledge base is The Universal Decimal Classification (UDC) [10].

In this illustration plain Digital Chart of the World (DCW) data are used [15]. The coastline database is the Global Self-consistent Hierarchical High-resolution Geography (GSHHG) [16], [17], which was mainly compiled from the World Vector Shorelines (WVS) [18], the CIA World Data Bank II (WDBII) [19], 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) [20] for visualisation.

Concrete details of knowledge complements and components have been provided [6]. 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,

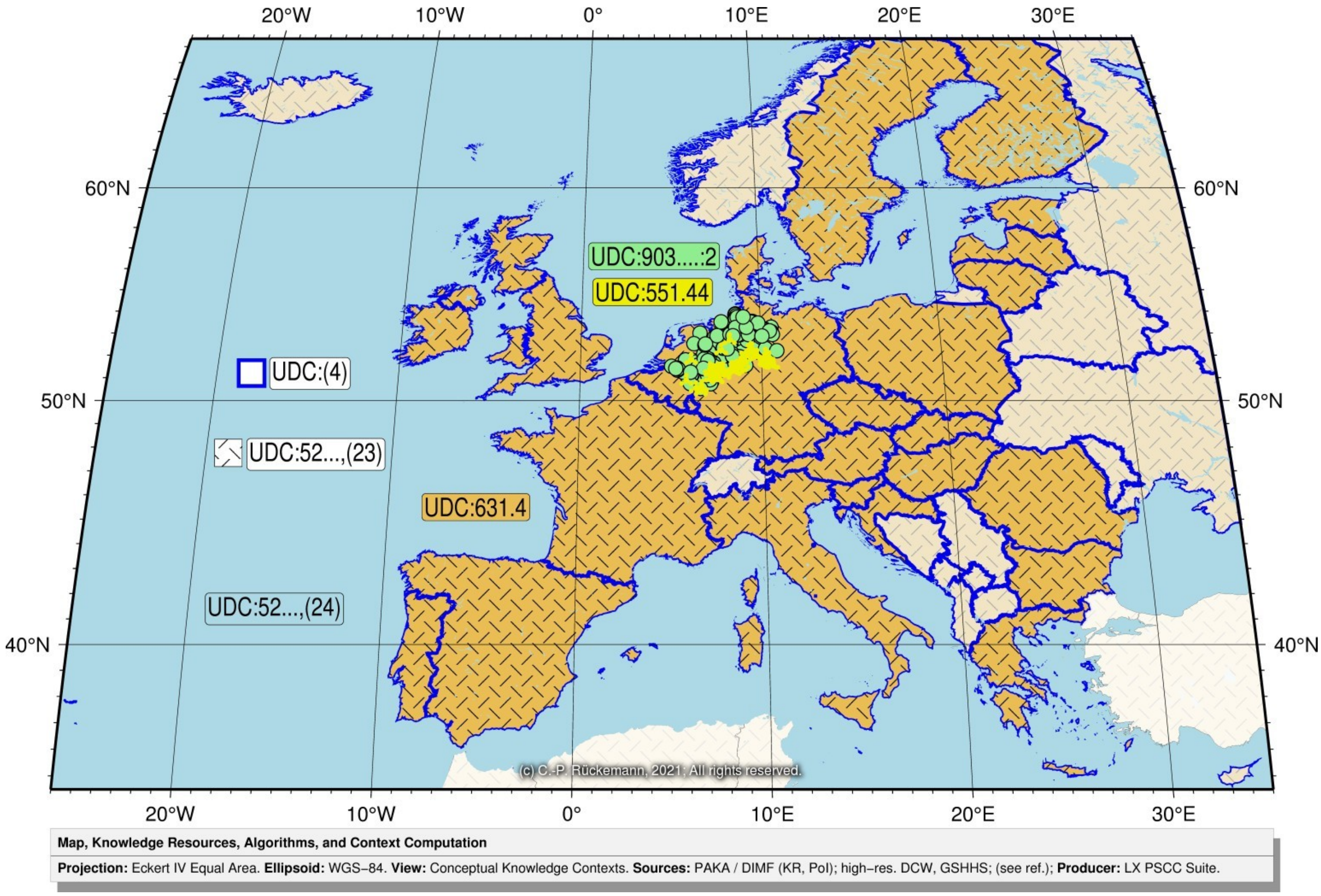

Figure 1. Resulting coherent conceptual knowledge integration sketch diagram showing knowledge resources for a prehistoric, natural sciences, and spatial contextualisation for excerpts of prehistoric cemeteries' and caves' distributions, remote sensing data, and soil properties with respective knowledge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

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. 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).

Many solutions resulting from the above scenario were implemented and realised on the fundament framework of flexibly coupled components. The following sections deliver the component reference implementations frame created resulting from the long-term research, achieving the framework for the required implementations and realisations and for the multi-disciplinary coherent knowledge integration. The component reference implementations frame provides a systematical approach for a large variety of coherent conceptual, consistent approaches for multi-disciplinary contextualisation for many scenarios beyond the examples for prehistory and prehistorical archaeology, natural sciences, and humanities.

V. Component reference implementations frame

The next sections give a compact overview of a major Component Reference Implementations (CRI) development stage edition (E.0.3.5) integrated with this research on knowledge complements and frameworks for coherent knowledge integration in prehistory, natural sciences, and humanities. 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 Knowledge Resources (KR) have been summarised [6].

The following component reference implementations provide a resulting, comprehensive set of complements and components required for an advanced practical long-term case scenario, integrating knowledge on prehistory and prehistorical archaeology, natural sciences, remote sensing, and soil science.

A. CRI: Conceptual knowledge frameworks

Conceptual knowledge frameworks were created as reference implementations and are further continuously in development and used in practice with ongoing long-term research and applied for KR [6], e.g.:

- *Prehistory-protohistory and archaeology Conceptual Knowledge Reference Implementation (CKRI)*, including multi-disciplinary contexts of natural sciences and humanities and any facets (E.0.4.4) [8] [21].
- *Mathematical and computational conceptual knowledge framework* [22].
- *Environmental information systems conceptual knowledge framework* [23].

Additional CKRI can be created by and for disciplines and scenarios and coherently integrated with CKRI already in use.

B. CRI: Conceptual knowledge base

Conceptual knowledge base is The *Universal Decimal Classification (UDC)* [10], a general plan for knowledge classification, providing an analytico-synthetic and faceted classification, designed for subject description and indexing of content of information resources irrespective of the carrier, form, format, and language. 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. UDC-based references for demonstration are taken from the multilingual UDC summary [10] released by the UDC Consortium, Creative Commons license [24].

C. CRI: Integration of scientific reference frameworks

Relevant scientific practices, frameworks, and standards from disciplines and contexts. Natural sciences, geosciences, and soil science are continuously delivering updated state of the art research and insight, including geodiversity and standardisation [25] [26]. 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* [13], [14] from the Food and Agriculture Organisation (FAO), United Nations.

D. CRI: Formalisation

All integration components, for all disciplines, require an explicit and continuous formalisation [27] process in order to conform with the information science principles according to the practices in the disciplines [28]. This includes knowledge objects and entities as well as procedural components (e.g., *C* [29], *Fortran* [30], *Perl* [31], *Shell wrapper*, *Julia* [32], [33], [34]), computation model support, e.g., *parallelisation standards, OpenMP* [35], [36], Reg Exp patterns, e.g., *Perl Compatible Regular Expressions (PCRE)* [37], further standard tools, e.g., *Structured Query Language (SQL)*, *Tool Command Language (TCL)* [38], Extract Transform Load (ETL), Extract Load Transform (ELT), and hybrid solutions. Addressing aspects of discipline related parole [39].

E. CRI: Methodologies and workflows integration

Methodologies for creating and utilising methods include model processing, remote sensing, spatial mapping, high information densities, and visualisation. Respective contextualisation of (prehistoric) scenarios should each be done under specific (prehistoric) conditions, especially supported by state-of-the-art methods, especially, consistent sources of standard algorithms [40], multi-dimensional criteria, spatial operations, interpolation geodesic computation [41], triangulation [42], gradient computation [43], and projection [44]. Workflow integration includes the overall spectrum of problem solving, e.g., mathematical algorithms, mathematical processes, filter processes, phonetic and linguistic context support [45]. Visualisation, *Generic Mapping Tools (GMT)* [20].

F. CRI: Prehistory Knowledge Resources

Common sources of information in many disciplines are often not yet aware of universal knowledge concepts and multilingual approaches. Common sources mostly lack sufficient coherency, consistency, and structure and more often they show to be fragmented and heterogeneous. 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)*, in continuous development for more than three decades [11] and is released by DIMF [12].

G. CRI: Natural Sciences Knowledge Resources

Several coherent systems of major natural sciences' context object groups from *KR realisations* have been implemented [6], [10], [46].

H. CRI: 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), Digital Terrain Model (DTM), and Digital Surface Model (DSM) representations* sources, e.g., from *satellites*, *drones* (raster data, RAdio Detection And Ranging (RADAR), Synthetic Aperture Radar (SAR), Light Detection And Ranging (LiDAR), etc.), *positioning/navigation* (common satellite systems / satellite navigation systems, e.g., Galileo, Europe; Global Positioning System (GPS), USA; GLObalnaja

NAwigazionnaja Sputnikowaja Sistema (GLONASS), Russia; Quasi-Zenith Satellite System (QZSS), Japan; Indian Regional Navigation Satellite System (IRNSS) / Navigation Indian Constellation (NAVIC), India), *z-value representations*, *distance representations*, *area representations*, *raster*, *vector*, *binary*, and *non-binary data*. Essential base context sources should provide *worldwide homogeneous and consistent data* [26] allowing extrapolation and interpolation in various dimensions, e.g., from the School of Ocean and Earth Science and Technology (SOEST), National Aeronautics and Space Administration (NASA), Goddard National Space Science Data Center (NSSDC), National Oceanographic and Atmospheric Administration (NOAA), Central Intelligence Agency (CIA) resources, European Community (EC) resources, and national and federal organisations and initiatives for further integration and future solutions.

I. CRI: Scientific context parametrisation

Scientific *context parametrisation of prehistoric targets* can use the overall insights, e.g., from geoscientific disciplines [47] [48]. A relevant example is contextualisation with palaeolandscapes [49]. In case of prehistory, parametrisation depends on the prehistorical context, e.g., the geoscientific parametrisation and geoscientific contextualisation depend of the respective selected prehistorical object groups and associated properties. The highly inter-dependent complexity can make the scientific parametrisation an extremely advanced long-term challenge.

J. CRI: Structures and symbolic representation

The deployment of long-term universal structure and data standards is essential. Relevant examples of sustainable implementations are *NetCDF* [50] based standards, including advanced features, hybrid structure integration, and parallel computing support (*PnetCDF*) and generic multi-dimensional table data, standard xyz files, universal source and text based structure and code representations, e.g., American Standard Code for Information Interchange (ASCII) and LaTeX [51].

Structure is an organisation of interrelated entities in a material or non-material object or system [46]. Structure is essential in logic as it carries unique information. Structure means features and facilities. There are merely higher and lower facility levels of how structures can be addressed, which result from structure levels. Structure can, for example, be addressed by logic, names, references, address labels, pointers, fuzzy methods, phonetic methods. ‘Non-structures’ can, for example, be addressed by locality, source, context, logic, attributes, size, quantity. Structure is and especially reflects knowledge (especially factual, conceptual, procedural, metacognitive, and structural complements), context, experience, persistence, reusability, sustainability, value, and formalisation, including abstraction and reduction. Structure systematics, meaning, levels of structures, and means of addressing were discussed in detail [46]. We should be aware that lower structure levels can only be addressed on higher formalisation levels, independent of the fact that structure may either be not available or not recognised. Substantial deficits of lower level structured knowledge representations cannot be compensated by (procedural) tools. Therefore, addressing structures on cognostic levels is preferable to isolated procedural means and can be utilised for symbolic representations. Symbolic representations of prehistoric context information include graphs, e.g., diagrams using visualisation techniques, for logical, quantitative, schematic, and semi-schematic characteristics. Concrete examples are relationships of entity representations, variables, topological and spatial properties, and combined representations of abstract and realia properties. Structures and standards, in integration with formalisation processes, knowledge system, and components should foster seamless long-term development and sustainable realisation. Nevertheless, the complements, which enable flexible automation capabilites are up to vast parts depending on the context of how realia are viewed and in consequence how they should be described and managed, e.g., by formalisation, standards, consistency, systematics, methodological procedures, structure, and object groups.

VI. Discussion

The presented practical component reference frame implementations are based on a number of component groups, which are in continuous long-term development. The methodology, methods, case scenarios and the fundaments of the component reference implementations and conceptual knowledge frameworks were lately publicly presented and discussed at the Informational Modeling - Theory and Practice - International Conference, Sofia, Bulgaria [8], at the International Conference on Mathematics of Informational Modeling, Varna, Bulgaria [52], both Bulgarian Academy of Sciences, at the Delegates’ Summit, Symposium on Advanced Computation and Information in Natural and Applied Sciences, Rhodes, Greece [53], and at the Machine Learning for Industry Forum hosted by the High-Performance Computing Innovation Center and Data Science Institute at the Lawrence Livermore National Laboratory, USA [54]. Practical applications and concrete developments of conceptual knowledge reference implementations and a component reference implementations frame were discussed regarding ongoing and future research initiatives in prehistory and prehistorical archaeology, natural sciences, and integrative industry applications. Conceptual knowledge solutions are recognised a fundament of future industrial learning, collaborative, and multi-disciplinary information science. The component reference implementations frame resulting from this research has shown to provide a flexible framework for the required implementations and realisations including the multi-disciplinary coherent knowledge integration. Especially, the respective conceptual knowledge reference edition implementation stages [55] (E.0.4.4 and future) to integrate seamlessly with the coupled components.

VII. Conclusion

The new component reference implementations frame enables efficient implementations and realisations of multi-disciplinary coherent conceptual and chorological context integration and contextualisation in prehistory and prehistorical archaeology. The frame allows coherent contextualisation in prehistorical archaeology and natural sciences even where contexts cannot be ‘sensed’ directly. The components allow a seamless integration of Conceptual Knowledge Reference Implementations (CKRI) for coherent conceptual and chorological context integration and contextualisation in prehistory and prehistorical archaeology.

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:

- Create (specialised) coherent CKRI.
- 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 continued development of components and reference implementations for creation of models for analysis and development of multi-disciplinary knowledge and context, taking new findings and context integration of application scenarios in prehistory and archaeology into account and further considering chorological and coherent conceptual knowledge contextualisation, especially regarding dedicated prehistory and prehistorical archaeology research cases.

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