Prehistory's and Natural Sciences' Multi-disciplinary Contexts: Contextualisation and Context Integration Based on Universal Conceptual Knowledge

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***Abstract*—This paper presents the results of the requirements study on a new integration system for conceptual contextualisation of prehistory's and natural sciences' universal multi-disciplinary contexts. The paper delivers the results of previous and ongoing research initiatives, which are to be integrated based on information science fundaments for a coherent conceptual integration, enabling consecutive coherent analysis. The methodological approach enables the inclusion of new insight and newly created knowledge, e.g., via deployment of knowledge resources and structures. The programmatic approach and new conceptual knowledge reference implementation span multi-disciplinary knowledge in a coherent, consistent, and multi-lingual way. The methodology to consistently integrate knowledge context from prehistory and archaeology disciplines with knowledge in natural sciences and humanities is accompanied by ongoing multi-disciplinary case studies implementing the required methods. The focus of this research is on knowledge-based methodologies and deployment of information science methods, especially, universal conceptual knowledge, for the goal of creating a component framework of reference implementations for coherent and general multi-disciplinary contextualisation and context integration, targeting the creation of new insight, strategies, and perspectives.**

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

I. INTRODUCTION

When dealing with context, the signification of the terms 'complex' and 'complicated' is often mixed up. Complexity is a concomitant phenomenon of context, which, when not well comprehended, appears complicated. Both, complexity and context, are linked by manyfold inter-dependencies and often experienced together. Context is witness-context in many cases, in prehistory and natural sciences. Understanding context and gathering complexity in a coherent, consistent, and methodological way are therefore important fundaments, which can lead to consequent systematical instrumentalisation, consecutive coherent analysis, and aspiring new insight.

The focus of this research is on knowledge-based methodologies and deployment of information science methods, especially universal conceptual knowledge, for the goal of creating a component framework of reference implementations for coherent and general multi-disciplinary contextualisation targeting the creation of new insight, strategies, and perspectives. This research is part of several extensive long-term strategies and concentrating on contextualisation and context integration for prehistory, protohistory, archaeology and their associated contexts, especially natural sciences and humanities. 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. From the knowledge point of view, also when looking on methodological conditions, prehistory shares many characteristics and factual conditions with natural sciences, e.g., geology and soil science. A coherent conceptual knowledge approach can enable to establish ties and building bridges between contributing knowledge, including future methodologies and contributions from disciplines.

The fundaments of terminology and understanding the essence of knowledge are layed out by Aristotle, being a central part of 'Ethics' [1]. Information sciences can very much benefit from Aristotle's fundaments and a knowledge-centric approach [2] but for building holistic and sustainable solutions, supporting a modern definition of knowledge and subsequent component instrumentation [3], they need to go beyond the available technology-based approaches and hypothesis [4] as analysed in Platon's Phaidon. Aspects of meaning can be described using knowledge complements, e.g., considering factual, conceptual, procedural, metacognitive [2], and structural knowledge. Especially, conceptual knowledge can relate to any of factual, conceptual, and procedural knowledge. To a comparable extent, metacognitive knowledge can relate to any of factual, conceptual, and procedural knowledge. Knowledge complements are a means of understanding, e.g., enabling advanced contextualisation, documentation, prospection, integration, and analysis. From an information science point of view, the classical fundaments of episteme, techne, and doxa are intrinsically tied complements. However, knowledge complements, when consequently applied, do not make the creation and development of resources instantaneously easier. They do not make problem solving algorithms simpler. Knowledge complements do not make scientific contexts obsolete, they do neither make qualified expertise unneeded nor do they lead to faster education or cheaper gain of research results and insight.

This paper presents the methodological and systematical fundaments and components for implementing a multi-disciplinary integration of prehistory and its context. The paper summarises the results of immanent milestones and, based on these, proposes the next complementary methodological and practical resources' developments. Further, details on complements and results of specific application scenarios will be discussed in separate extended papers.

The rest of this paper is organised as follows. Section II gives the essential background of motivation resulting from different disciplinary views. Section III presents an overview of pre-existing and deployed component developments at this stage, which have been in continuous further development. Section IV introduces to disciplinary background and requirements. Section V presents the methodological fundaments and components. Section VI presents the respective results of component implementations of the integration. Sections VII and VIII discuss the lessons learned and summarise conclusions and future work.

II. Motivation

Complexity is carrying information. Therefore, from information science point of view, we should take care not to loose complexity whenever dealing with information. The complexity of appearing context is commonly even increased when applying methods from multiple disciplines. So far, there are no other comparably holistic and systematical approaches and implementations on conceptual contextualisation known and published besides the presented approach. Contrary, during the last decades, it has become common practice to tackle challenges regarding knowledge and related content solely with procedural approaches, contrary to the fact that creation processes, handling, and management may allow more effective and efficient measures in context of analysis, long-term development of resources, computation, and processing, Common ways of implementing procedural approaches as plain technical solutions are often neither effective nor efficient. In addition, such approaches often lack long-term adaptability and scalability.

How can we create a suitable, practical system of coherent knowledge? Such a system 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 [5]. Many facets of knowledge, including prehistory, need to be continuously acquired and reviewed [6]. Knowledge itself is part of cognitive processes and requires an understanding of epistemological fundaments, depending on participated disciplines and views [7] [8].

We should therefore create a system of balanced fundaments of sustainable, complementary solutions based on information science and contextualisation-aware methodologies and complements [9], which allows the application of coherent conceptual knowledge in theory and practice. The conceptual knowledge approach should provide facilities expressing instances of mental concepts and the state of research of their perception. The creation of object types may be influenced by criteria, e.g., by education, experience, and social context. The approach should enable further development of practical disciplinary terminology assignment, e.g., adaption and synchronisation of terminology.

III. Pre-existing, ongoing developments

The next sections briefly summarise components used for addressing knowledge with multi-disciplinary Knowledge Resources (KR).

A. Conceptual knowledge frameworks

The following frameworks are developed and used in practice with ongoing long-term research and applied for multi-disciplinary KR. The framework implementations are addressing conceptual knowledge for the following disciplines and scenarios.

- Environmental information systems conceptual knowledge framework [10].
- Mathematical and computational conceptual knowledge framework [11].
- Prehistory-protohistory and archaeology Conceptual Knowledge Reference Implementation (CKRI), including multi-disciplinary contexts of natural sciences and humanities [9].

Based on information sciences fundaments, these coherent frameworks are complementary and fully consistent. The more, the prehistory framework was created over the last years and is consequently in continuous further development with ongoing research projects, application scenarios, and studies.

B. Conceptual knowledge base

The Universal Decimal Classification (UDC) [12] is a general plan for knowledge classification. UDC is also the world's foremost document indexing language in the form of a multilingual 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 provides an analytico-synthetic and facetted classification. UDC schedules are organised as a coherent system of knowledge with associative relationships and references between concepts and related fields and are used by more than 150.000 document collections worldwide. UDC-based references in this publication are taken from the multilingual UDC summary [12] released by the UDC Consortium under a Creative Commons license [13]. Facets can be created with any auxiliary tables. Notations can be used to refer to external concepts.

C. Conceptual knowledge pattern 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 [14]. Comprehensive focussed subsets of conceptual knowledge can provide excellent modular and standardised complements for information science based component implementations, e.g., for environmental information management and computation [10]. The presented implementations strictly follow the fundamental methodological algorithm base of the the Conceptual Knowledge Pattern Matching (CKPM) methodology [5], providing and accessing knowledge object patterns based on the Superordinate Knowledge Methodology, which allows systematical use and thorough processing. Respective results from a methodology targeting structures, including implementation, and knowledge-aware application of the methodology were layed out and are available with practical examples [15]. Core eager beaver procedure- and structure-based implementation components, grep and join, are written in C, as those commonly known. Modules can deploy Perl Compatible Regular Expressions (PCRE) [16] syntax for specifying common string patterns. The PCRE approach is independent from the procedural realisation using Shell and Perl [17] for component wrapping purposes with case studies and implementations.

IV. Consideration of disciplinary background

Prehistoric context, even for chorologically, chronologically, and thematically restricted object groups [18] [19] [20] comprises of a wide and highly variable spectrum of knowledge, applied approaches, and formalisation, including abstraction [21] and documentation [22]. Almost all knowledge is further referring to complex contexts of many associated disciplines and views.

In complex scenarios, like multi-disciplinary prehistoric realia founded contexts, we should utilise as much complexity and structure with knowledge complements as possible in order to achieve a high level of integration of factual, conceptual, and structural but also of procedural and metacognitive knowledge. In practice, these approaches are often not followed. In many cases, simple convenience of workflow tasks might suggest to integrate 'data' available as is. Even standards and implementations may not be optimal, they can result from the fact that information and data are often determined by technological means. The result may be a limitation regarding the fundamental coherence of knowledge and it may limit the applicability and use of methods and algorithms.

Basic deficits of simplified approaches and many commonly used frameworks (e.g., context-unaware approaches for maps/earth services) make these approaches undesirable for a general and coherent scientific and methodological realisation.

Further, the application of not well satisfying approaches and methodological deficits, especially in multi-disciplinary context, are often fragmented, heterogeneous, and lacking required coherence and precision [23] or require unnecessary estimations and approximations [24].

Further, in addition to such contrary practice there are multifold cases, which should direct to more feasible approaches, e.g., in situations

- when terminology does –in any case– not reflect the context of respective findings,
- when relocated objects require contextualisation and descriptive conceptual knowledge,
- where indications of resources are available without respective artefacts,
- isolated findings of various levels exist,
- when objects with presently isolated contexts require coherent chronology.

Examples of associated, guiding questions are: How can existing and emerging knowledge from prehistory and other disciplines be methodologically integrated? Which multi-disciplinary contexts and approaches can be considered on a coherent, consistent information science base? What are context areas of special characteristics, e.g., where are possible regions of interest and further research? Which fundaments and component implementations should be in focus of contextualisation?

A basic approach for prehistoric contextualisation should be characterised by modular components and premises, namely,

- a coherent, multi-disciplinary methodology, spanning disciplines and fields,
- an overall coherent and consistent knowledge base,
- principle concepts for knowledge description,
- implementing the state of the art in information science and knowledge,
- considering long-term time ranges for continuous developments,
- enabling wide context integration,
- enabling representation of different views,
- enabling representation of different actual perceptions,
- allowing to complement terminology where required,
- and integration of standards and frameworks.

The premise of coherency of the knowledge base is important in a way that solutions should not be restricted to procedural components and interfaces, which intrinsically require additional multi-level formalisation. The coherent approach can provide required descriptive complements to otherwise prescriptive terminologies. The integration should be aware of cognitive visualisation aspects. The contextualisation should further enable to continuously integrate results of past and ongoing research of prehistoric on-site context surveys.

V. Methodological Fundaments and Components

The methodological and systematical fundaments for contextualisation of prehistory, protohistory, and contexts require modularity and flexibility with structure levels and multi-dimensional knowledge context, especially regarding

- prehistoric object groups,
- prehistoric objects,
- inter-object group context and references,
- chorological and chronological context,
- context correlation for soil context,
- material context, and
- toponymic context,

with further natural and environmental context, regarding methods and extendability, valorisation, analysis, and potential for new insight. At these conditions and based on the previous research and project practice, basic fundaments are:

- Universal, coherent, and consistent conceptual knowledge system.
- Integration of scientific reference frameworks from disciplines and contexts.
- Formalisation for complements, coherence, consistency.
- Methodologies, general problem solution, workflow integration. Implementation and deployment of methods and algorithms.
- Prehistory and protohistory knowledge resources and complements.
- Natural sciences knowledge context resources and complements.
- Inherent representation groups of context resources.
- Scientific context parametrisation.
- Universal structures and data standards.
- Facilities for analysis.
- Spatial mapping.
- Symbolic representation of context information.
- Facilities for automation.
- Long-term development and sustainability.

Besides obvious reasons, e.g., spatial ranges, serious dependencies are made up by conditions of required mathematical algorithms and the context of available data. These dependencies cannot be overcome in many cases as, e.g., it is not possible to get direct data from the original context of a prehistorical site. Targeting contextualisation, the conceptual implementation should integrate knowledge for natural conditions and processes, soil-affine and respective soil-related, e.g., agricultural or geoforensic, contexts. The implementation should consider different systems of chorologies and chronologies, e.g., prehistorical and geological time frames, palaeolithic to neolithic in coexistence with Pleistocene to Holocene and other conceptual and absolute chronologies. The achieved results of respective developments and implementations of the components will be discussed in the following sections.

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VI. Methodological component implementations

Focus is on required methodological, conceptual, non-procedural, non-interactive, and non-technical components. Practical components for systematical and methodological implementations are defined and developed according to the analyses in already realised projects and case studies of practical scenarios as cited here and described in the references. Therefore, numerous components and tools, which have shown not to seamlessly integrate in long-term development environments are not deployed here. Please refer to the secondary literature for components less suitable for the intended integration purpose. The overall component developments required for this research are inter-depending and not linear. The integrated components should be kept modular on epistemological base.

A. Conceptual knowledge and complements

The universal conceptual system is deploying the knowledge framework based on The Universal Decimal Classification (UDC) [12]. The approach enables to add multi-disciplinary knowledge to a knowledge base of a discipline on a coherent conceptual knowledge base, e.g., refer further ‘hard facts’, and to allow further advanced critic factual and cognostic reception. Central component is the prehistory-protohistory and archaeology CKRI including multi-disciplinary natural sciences and humanities contexts [9].

B. Integration of scientific reference frameworks

The integration includes relevant scientific practices, frameworks, and standards from disciplines and contexts, e.g., natural sciences. Geosciences and soil science are continuously delivering updated insight on state of the art research, including the geodiversity and standardisation [25] as required for contextualisation. A practical reference implementation coherent with the contextualisation of prehistory-protohistory and archaeology conceptual knowledge [9] is currently in development within a long-term project accompanying this research. 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.

C. 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. This includes knowledge objects and entities as well as procedural components and addressing aspects of discipline related parole [28].

D. 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, supported by state-of-the-art methods, especially, consistent sources of standard algorithms [29], multi-dimensional criteria, spatial operations, interpolation geodesic computation [30], triangulation [31], gradient computation [32], and projection [33]. Workflow integration also includes the overall spectrum of problem solving, e.g., mathematical algorithms, mathematical processes, filter processes, but also phonetic and linguistic context support [34].

E. Prehistory Knowledge Resources

Common sources of information in many disciplines are often not yet aware of universal knowledge concepts and multilingual approaches. Common sources are in many cases not sufficiently coherent, consistent, and structured and more often they show to be fragmented and heterogeneous. In order to be independent of these basic shortcomings, all of 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 [35] and is released by DIMF [36]. Table I shows a plain representation excerpt of a KR based system [12] [15] of major discipline object groups implemented for prehistory and protohistory and their chorological context.

TABLE I. SYSTEM OF DISCIPLINE OBJECT GROUPS AND CONCEPTUAL VIEW GROUPS [12]: PREHISTORY AND PROTOHISTORY (EXCERPT).

Major Object Group	*Conceptual View Group*
Ritual places, burials	UDC:903
Cemetery	UDC:903
Barrow	UDC:903
Dolmen	UDC:903
Urn	UDC:903
Earthworks	UDC:903
Settlements	UDC:903
Fortifications	UDC:903
Architectures	UDC:903
Structures and arrangements	UDC:903
Timber	UDC:903
Stone	UDC:903
Relics, organic and non-organic	UDC:903
Organic	UDC:903
Metal	UDC:903
Artefacts, organic and non-organic	UDC:903
Rock art	UDC:903
Sculptured objects	UDC:903
Resources (usage, mining, etc.)	UDC:903

The conceptual view group is prehistory, prehistoric remains, artefacts, and antiquities. A prehistoric valorisation sample is the swimming reindeer [37], included in detail in [9]. The resources have been in continuous development, which follows information science research, and can be consistently and seamlessly deployed with integrated conceptual reference frameworks and components.

In addition, the conceptual views groups are a unique, flexible, and extendable approach of addressing multi-lingual verbal descriptions with a systematic approach and standardised implementation framework for coherent multi-disciplinary and multi-dimensional scenarios, beyond plain representation.

F. Natural Sciences Knowledge Resources

Table II shows a plain representation excerpt of an implemented system of major natural sciences’ context object groups from KR realisations [12] [15].

TABLE II. SYSTEM OF CONTEXT OBJECT GROUPS AND CONCEPTUAL VIEWS GROUPS [12]: NATURAL SCIENCES / NATURE (EXCERPT).

Major Object Group	*Conceptual View Group*
Landmarks	UDC:55+539+63
Height	UDC:55+539+63
Depth	UDC:55+539+63
Caves	UDC:55+539+63
Natural resources	UDC:55+539+63
Rock outcrops	UDC:55+539+63
Well springs	UDC:55+539+63
Soil features	UDC:55+539+63
Volcanological features	UDC:55+539+63
Impact features	UDC:55+539+63

The conceptual view group is earth sciences and geological sciences, physical nature of matter, agriculture and related sciences, including geophysics, historical geology, and palaeogeography, soil science and research.

G. Inherent representation groups

Table III shows a plain representation excerpt of major discipline and context object groups regarding their inherent representation and common utilisation.

TABLE III. DISCIPLINE AND CONTEXT OBJECT GROUPS AND CONCEPTUAL VIEW GROUPS [12]: INHERENT REPRESENTATION (EXCERPT).

Major Object Group	*Conceptual View Group*
Points, (Points of Interest, PoI)	UDC:52+004
Polygons	UDC:52+004
Lines	UDC:52+004
Digital Elevation Model (DEM) representations	UDC:52+004
z-value representations	UDC:52+004
Distance representations	UDC:52+004
Area representations	UDC:52+004
Raster	UDC:52+004
Vector	UDC:52+004
Binary	UDC:52+004
Non-binary	UDC:52+004

The conceptual view group is astronomy, astrophysics, space research, and geodesy, computer science and technology, computing, and data processing, including earth measurement, field surveying, photogrammetry, remote sensing, data processing, interpretation, mapping, data representation, data handling, and computer languages.

H. Scientific context parametrisation

Scientific context parametrisation of prehistoric targets can use the overall insights, e.g., from geoscientific disciplines [38] [39]. A relevant example is contextualisation with palaeolandscapes [40]. 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.

I. Structures and symbolic representation standards

The deployment of long-term universal structure and data standards is essential. Relevant examples of sustainable implementations are NetCDF [41] 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, e.g., American Standard Code for Information Interchange (ASCII). Structure is an organisation of interrelated entities in a material or non-material object or system [15]. 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 [15]. 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. The 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.

VII. DISCUSSION

This section reviews the status of integration potentials and an outlook on concrete targets based on the lessons learned from the methodological component implementations. The component related processes are challenging and not trivial, especially formalisation and parametrisation. This is the more true for the integration processes. The resulting component base is the start of the long-term integration project on contextualisation for prehistory and multi-disciplinary contexts. All the presented components were created, developed, and evaluated with the referred practical project results and case studies. The conceptual knowledge reference implementations, especially the prehistory CKRI and components showed that they are best choice addressing required properties and features for the tasks. The presented components' set of reference implementations and components also allows further development, targeting the integration for coherent contextualisation including required standards from information science, conceptual knowledge, prehistory and archaeology, natural sciences

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and geosciences, soil science, satellite and spatial data, and processing algorithms, for the purpose of contextualisation and further utilisation and prospection in prehistory and context.

It should be explicitely noticed, that the integrated methods, resources, and workflows have to support features beyond methodological compatibility, suitability, modularity, and flexibility on the task, e.g., with development, storage, transfer, and utilisation. Especially, the presented conceptual knowledge system enables to respect the rights of participated parties and conform with and adhere to intellectual properties, privacy, and licensing of resources and components, e.g., with intermediate, and resulting structures, formats, and procedural components.

In consequence, practical integration can refer to involved resources and components from all disciplines, prehistory, geosciences, soil science, remote sensing, application of reference implementations and standards, creation of knowledge, procedural realisations, e.g., algorithms and model processing, and results, e.g., symbolic representation of prehistoric context.

VIII. Conclusion

The focus of this research is on knowledge-based methodologies and deployment of information science methods, especially universal conceptual knowledge, for contextualisation and context integration of multi-disciplinary contexts of prehistory and natural sciences, which can enable coherent future analysis. The long-term research projects in different disciplines leading to this publication contributed to the achieved goal to create a component framework of reference implementations for coherent and general multi-disciplinary contextualisation, which represents more than its component parts. The integration enables to deal with knowledge complements, e.g., factual, structural, and formalised like time periods but also with metacognitive like experience, meaning, and symbolism. The presented results are nevertheless the start of a consecutive long-term integration project and continuing projects in participated disciplines. The presented methodological approach allows to systematically overcome conceptual fragmentation and to foster on a multi-level coherency for multi-disciplinary knowledge. The multi-lingual conceptual reference implementation allows to address problems of various language dependent fragmentation, e.g., to resolve national and local terminology fragmentation. This is increasingly relevant for coherency of inter-disciplinary knowledge in contextualisation.

The new integration system with its components enables a coherent conceptual integration of prehistory and context disciplines and can foster the consideration and visibility of inherent aspects. Methodology and implementation allow a wide range or multi-disciplinary contexts and approaches for prehistoric context research for arbitrary regions on interest based on context knowledge, which can globally kept homogeneous and consistent as allowed by publicly available state-of-the-art resources. Examples are geoscientific and mathematical parametrisation and model computations for prehistoric scenarios. The developed reference implementations and components, including the prehistory CKRI and the geoscientific reference implementations, have been in continuous further development to address the continuous development of multi-disciplinary knowledge resources and new methodological implementations. Conceptual knowledge system and component implementations allow to address and correlate contexts described by geoscientific disciplines, e.g., diversity of soil and properties relevant for prehistory and respective research.

Overall, in result, contextualisation fosters careful and diligent scientific interpretation. Further research, besides global applicability of the methodology and implementations, can focus on the Central European supra-regional studies and on micro-regional studies in the Northern Germany (North-Rhine Westphalia, Lower Saxony) and The Netherlands coast areas. Future research targets further long-term development of a consistent conceptual knowledge framework focussing on prehistory and includes context-aware surveys on prehistoric object groups, multi-disciplinary contextualisation of geodiversity and prehistoric scenarios, modular integration, analysis, and symbolic representation components for prehistory and context disciplines. The integration and priorities with information science research depend on the state-of-the-art results and development in contributing disciplines.

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