Prehistorical Archaeology Discipline's Contextualisation Facts and Workflow Logic: Complements-Components Blueprints for the Creation of Efficient Coherent Multi-disciplinary Conceptual Knowledge-based Discovery

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***Abstract*—This paper presents the results of the methodological discovery and parallelisation of workflow logic of prehistorical archaeology discipline's contextualisation, based on coherent multi-disciplinary conceptual knowledge. The goal is the creation of efficient, flexible, and sustainable contextualisation workflows, also providing efficient parallelised frame conversion. Implementations and realisations are enabled by the latest versions of the prehistory-protohistory and archaeology conceptual knowledge reference implementation and the component reference implementations framework. The paper provides the results on archaeological / prehistorical facts, universal contexts, and logical and formal entities, factual, conceptual, and procedural complements, components, and results required for exemplary practical hard criteria and fact-based contextualisation by the disciplines and even for consequent creative historico-cultural exploitation. Future research will address the creation and further development of a conceptual knowledge reference implementation and a component reference framework for coherent multi-disciplinary conceptual contextualisation, enabling multi-disciplinary equal footing with contributions from all scientific disciplines for example for prehistorical archaeology knowledge integration, contextualisation and analysis with prehistorical and archaeological knowledge resources.**

Keywords–Prehistory and Archaeology; Discipline's Facts and Workflow Logic; Fact-based Contextualisation; Historico-cultural Interpretation; CKRI and CRI Framework.

I. Introduction

The need to implement workflows of many disciplines beyond 'manual operation' has been continuously increasing over the last decades. In practice, we can also see a strong motivation for sustainable Knowledge Resources (KR) creation and development and efficient employment of resources, e.g., with high performance computation and storage.

After reading, writing, and arithmetic are established and accepted as general competences, the capabilities of achieving efficient analysis and contextualisation solutions are becoming 'state-of-the-art' increasingly important personal competences in the sciences. Efficiently and sustainably organising and de-isolating knowledge complements, the results of research, within a discipline is at least as important as its short term analysis. These organisation processes cannot refer only to the data if they should be useful for reuse of knowledge and insight. Therefore, such organisation can in no ways be seen technically or being task of third parties without risk of losing the competence on fact-based methods, insight, and interpretation. Additionally, organisation of its knowledge complements is a core scientific matter of any discipline and closely associated with the methods employed, with the ongoing analysis processes, and with the further interpretation potential. In accordance with best practice, any scientists dealing with methodological workflows in a discipline, e.g., when applying a method, should know and practice themselves the way steps can be created, organised, and implemented, e.g., the algorithms, symbolic representation, and the structure and computation related characteristics. This practice is especially relevant with all knowledge complements or in other words the non-technical aspects of workflows in prehistorical archaeology. Scientific work, including state-of-the-art practices in archaeological disciplines and humanities, comprise of a number of essential principles, including further continuous employment of valuation methods for new factual knowledge and insights, re-contextualisation and resources development, and consequent fact-based contextualisation, analysis, and interpretation. When done properly, the tasks including contextualisation allow to practice equal footing with contributing scientific disciplines. Numerous surveys and studies were conducted for archaeological and prehistorical cases and multi-disciplinary contexts during the last decades, e.g., specific object groups' contextualisation [1] and discovery [2] and providing factual knowledge for interpretation, including historico-cultural contexts. The Prehistory and Archaeology Knowledge Archive (PAKA) is continuously collecting [3] new knowledge and insight. This research delivers the respective blueprints resulting from previously unpublished contexts and workflows and efficient workflow implementations proven sustainable over many years and widely reusable.

The rest of this paper is organised as follows. Section II presents the fundaments and state-of-the-art methodological implementations and realisations employed. Section III presents the results of the contexts and workflow logic for processes in prehistorical archaeology, factual/conceptual and procedural complements. Section IV delivers the discipline's results, efficiency results, and discussion for the presented contexts and workflow logic cases. Section V summarises lessons learned, conclusions, and future work.

II. Fundaments and Previous Work

Two major practical reference implementations were deployed for full implementations, realisations, and continuous further developments: the latest versions of the prehistory-protohistory and archaeology Conceptual Knowledge Reference Implementation (CKRI) [1] and the Component Reference Implementations (CRI) framework [4] for conceptual knowledge-based context integration, complements processing, and geoscientific visualisation. CKRI provides the universal knowledge framework, including multi-disciplinary contexts of natural sciences and humanities [5]. CRI provides the required component groups and components for the implementation and realisation of all the procedural modules. The reference implementations are based on the fundamental methodology of knowledge complements [6], considering that many facets of knowledge, including prehistory, need to be continuously acquired and reviewed [7]. Creating contextualisation requires to coherently integrate multi-disciplinary knowledge and to enable symbolic representations. Realisations need to integrate a wide range of components as required from participating disciplines, e.g., for dynamical processing, geoprocessing, spatial contextualisation. Prehistoric object groups and contexts are taken from the latest edition of PAKA, which is in continuous development for more than three decades [8], and from The Natural Sciences KR (NatSciKR), all released by DIMF [3]. The PAKA and The NatSciKR support Factual, Conceptual, Procedural, Metacognitive, Structural (FCPMS) knowledge complements [9] and enable seamless coherent multi-disciplinary conceptual knowledge integration for workflow procedures. systematical and methodological approaches based on CKRI. CKRI references are illustrated for demonstration via the multi-lingual Universal Decimal Classification (UDC) summary [10] released by the UDC Consortium under Creative Commons license [11].

III. Discipline's Contexts and Workflow Logic

Prehistorical archaeology discipline's resulting contexts and workflow logic are often matter of multi-disciplinary long-term research, which requires universal context identification and assignment to contributing scientific disciplines.

A. Resulting Factual and Conceptual Complements Blueprint

The discipline's factual and conceptual knowledge complements and major logical and formal entities resulting from the long-term surveys and practical implementations are given in Table I. Employed resources are High Resolution (HR) Digital Elevation Model (DEM) data, e.g., (Space) Shuttle Radar Topography Mission (SRTM) data [12], updates [13], and further satellite data. Common DEM can be supplemented by local Light Detection And Ranging (LiDAR) data for special features and resolutions. DEM data for spatial contexts is used via Network Common Data Form (NetCDF) [14], developed by the University Corporation for Atmospheric Research (UCAR/Unidata), National Center for Atmospheric Research (NCAR). KR and complement implementations in contributing contexts and disciplines are PAKA and NatSciKR [3] accompanied by HR Digital Chart of the World (DCW) [15], and Global Self-consistent Hierarchical High-resolution Geography (GSHHG) [16]. The symbolic representation of the contextualisation can be done with a wide range of methods, algorithms, and available components, e.g., via LX Professional Scientific Content-Context-Suite (LX PSCC Suite) [17] deploying the Generic Mapping Tools (GMT) and integrated modules [18] for visualisation. The GMT suite application components are used for handling the spatial data, applying the related criteria, and for the visualisation. For sustainability we also consequently employ xyz files in GMT, e.g., Point of Interest (PoI) and Point of Discovery (PoD) contexts. Signatures and Colour Palettes (CPT) can also be flexibly integrated via GMT. Mostly all contexts and object groups are in continuous development, based on their structural implementations. Practically all contexts are dealt with employing the CKRI and its facets and operation facilities. Many properties of the contexts, e.g., chorological and chronological properties, can be addressed using international standards, e.g., for georeferencing and time. The consequent knowledge approach enables a wide range of workflow creation and analysis, in the scenarios discussed here ranging from fact-based contextualisation to consequent fact-based historico-cultural interpretation. The results allow even further consequent creative historico-cultural exploitation.

B. Resulting Procedural Complements Blueprint

The discipline's resulting procedural complements (the knowledge complements) and the corresponding workflow implementation resulting from the long-term surveys and practical implementations are given in Table II. The implementations are designed for end-user deployment by members of every responsible discipline dealing with their major logical and formal entities. The matrix shows context / object groups, required logical and formal workflow entities (major processing groups pre, main, post), examples of their symbolic representation, structure and procedure implementations. The table confirms that all contexts and object groups are in continuous further development, including the implementations of knowledge complements, e.g., factual, conceptual, procedural, and structural, which is a major achievement for scientific best practice and sustainability. The characteristics include the contexts addressed with CKRI and georeferencing, as well as the potential of mostly all contexts can be deployed in workflow parallelisation. The table especially lists excerpts of embarrassingly (E) and loosely (L) parallelisation features. The components of the workflow blueprint allow very high flexibility for fact-based methods and context integration of scientific, fact-based symbolic representation, e.g., the symbolic representation of archaeological, prehistorical contexts requires the employment of different geographic projections, e.g., geospherical orthographic, isometrical, and equal area. Projections can be flexibly implemented via GMT [19] and via PROJ [20]. Besides the implemented components we already named: The workflow allows processing usable for most disciplines, Area of Interest (AoI) calculations, regular expression patterns for context structures, e.g., via Perl Compatible Regular Expressions (PCRE) [21]. Attributations not applicable (n.a.) are marked accordingly. Workflow output, e.g., frames and visualisation can be created for many common structures, e.g., Joint Photographic Experts Group (JPG), Portable Network Graphics (PNG), and Portable Document Format (PDF), as well as Motion/Moving Pictures Expert Group, version 4 (MP4). Transformation can also be done for Keyhole Markup Language generation.

Multi-dimensional or sequences of view, e.g., focus dependent views for knowledge dimensional computation per object, are implemented via OpenMP [22] and specifications [23], e.g., . Job parallel procedures, e.g., knowledge objects and resources localities, are supported by respective modular solutions [24].

IV. Discipline's Results and Workflow Efficiency

A. Discipline's Workflow: Parallelisation and Results

Table III shows the scalability of the example workflow procedure for parallelised processing parts (pre, timing; main, parallelisation; post, batch) of the coherent multi-disciplinary conceptual knowledge. The results are referring to a scenario of a set of 1440 frames created in parallel for 4 k canvas size for a 60 s sequence with a rate of 24 FPS (Frames Per Second).

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TABLE I. PREHISTORICAL ARCHAEOLOGY DISCIPLINE'S CONTEXTS AND LOGICAL / FORMAL ENTITIES: RESULTING FACTUAL / CONCEPTUAL CONTEXTUALISATION MATRIX IMPLEMENTED FOR MAJOR COMPLEMENTS AND COMPONENTS (EXCERPT).

Context / Discipline / Object Group	*Logical / Formal Entities*	*Symb. Repr. (Example)*	*Structure Impl. (Example)*	*In Dev.*	*CKRI*	*Georef.*	*Parallelisation E*	*L*
			Factual / Conceptual Domain (Focus Complements: FCPMS)					
Hybrid	(Spatial) structure	Signature / CPT	netCDF, GMT, LX PSCC	✓	✓	✓	✓	✓
		HR DEM	netCDF, GMT, LX PSCC	✓	✓	✓	✓	✓
		SRTM	netCDF, GMT, LX PSCC	✓	✓	✓	✓	✓
		LiDAR	netCDF, GMT, LX PSCC	✓	✓	✓	✓	✓
Point	Singular structure	Signature / Symbol	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Prehistorical archaeology		PAKA	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Settlements		PAKA	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Ritual places		PAKA	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Notable objects		PAKA	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Geophysics		NatSciKR	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Impact craters		NatSciKR	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Planetology		NatSciKR	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Plate tectonics features		NatSciKR	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Geology		NatSciKR, PAKA	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Mineral resources		NatSciKR, PAKA	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Pedology		NatSciKR	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Soil characteristics		NatSciKR	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Volcanology		NatSciKR	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Volcanological features		NatSciKR	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Speleology		NatSciKR, PAKA	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Caves		NatSciKR, PAKA	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Oceanography		NatSciKR, GSHHG	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Bathymetry features		NatSciKR	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Hydrology		NatSciKR	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Mobility, transport		PAKA	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Pre-modern trackways		PAKA	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Linguistics		PAKA	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Open field names		PAKA	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Geography		NatSciKR	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Humanities, administrative		NatSciKR, DCW	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
...	...	...	...	...	...	...	...	...
Line / Polygon	Linear structure	Signature	xyz, GMT, LXPSCC	✓	✓	✓	✓	✓
Prehistorical archaeology		PAKA	xyz, GMT, LXPSCC	✓	✓	✓	✓	✓
...	...	...	...	...	...	...	...	...
Polygon	Areal structure	Signature	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Prehistorical archaeology		PAKA	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
...	...	...	...	...	...	...	...	...
Bathymetry features		GSHHG, DEM	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓
Administrative features		DCW	xyz, GMT, LX PSCC	✓	✓	✓	✓	✓

The architecture choosen for this realisation is an efficient 36-core-based Central Processing Unit (CPU) (Intel Xeon), which is taking into account that we commonly use 36 cores for many basic global approaches, e.g., considering 360 degrees of a global model. Precondition for parallelisation is sufficient memory for parallel use of integrated resources. Considering the employed resources, especially SRTM / NetCDF and KR, 128 GB RAM (Random Access Memory) for 36 parallel processes is comfortable when data limits are cut to the limits required for the algorithms with the range of a few hundred kilometres area per object entity.

TABLE III. SCALABILITY OF DISCIPLINE'S WORKFLOW (EXAMPLE RUNS, PARALLELISED PROCESSING KR AND CONTEXT RESOURCES).

Threads (Cores)	*Wall Time*				
	Pre, Timing	*Main, Parallel*	*Post, Batch*	*ΣPre, Main, Post*	
1	1145 s	2581175 s	84972 s	2667292 s	$\approx 741\,h$
18	526 s	143668 s	4759 s	143668 s	$\approx 40\,h$
36	262 s	71833 s	2386 s	74481 s	$\approx 21\,h$

The parallel instances are allowed for 90 GB HDD (Hard Disk Drive) space and separate 50 GB SSD (Solid State Disk) space for highly volatile data of parallel instances. Wall and compute times, especially of multi-dimensional workflow results, can greatly be reduced from the integrated parallelisation, which makes the procedural solution highly scalable. The wall times for thread numbers confirm the high scalability when implementations of the workflow are using higher numbers of threads. Many practical workflows may contain some parts which cannot be reasonably parallelised. This is especially true for scientific tasks with a certain complexity. Anyhow, the percentage of non parallelised parts is very low with CKRI and the CRI framework. However, individual instances may show non-linear characteristics due to instance content and references, e.g., different satellite data, different data types, and different knowledge complements. For large sets, hundreds up to thousands of CPU cores were employed, so parallelised wall times per object can be very reasonably reduced from days to hours or even minutes, e.g., for warning and tracking systems.

The following results from the above discipline workflow show an excerpt of eight frames from a large frame sequence for calculated Areas of Interest (AoI) contexts in top views (Figure 1). Ellipsoid is World Geodetic System 84 (WGS-84). Projection for frames is Lambert Azimuthal

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TABLE II. BLUEPRINT OF PREHISTORICAL ARCHAEOLOGY DISCIPLINE'S WORKFLOW LOGIC: RESULTING PROCEDURAL CONTEXTUALISATION MATRIX, FROM FC (TABLE I), IMPLEMENTED FOR MAJOR COMPLEMENTS AND COMPONENTS, INCLUDING PARALLEL FRAME CONVERSION (EXCERPT).

Context / Discipline / Object Group	*Logical / Formal Entities*	*Symb. Repr. (Example)*	*Struc. / Proc. Impl. (Example Complement / Environment)*	*In Dev.*	*CKRI*	*Georef.*	*Parallel. E*	*L*
			Procedural Domain (Focus Complements: FCPMS)					
Selection, preparation (KR)	Pre-processing	Pre-routines	CKRI, PCRE, … / LX PSCC	✓	✓	(✓)	(✓)	(✓)
Context resources	Pre-processing	Pre-routines	netCDF, CKRI, PCRE, … / LX PSCC	✓	✓	(✓)	(✓)	(✓)
Sequence	Pre-proc., timing structure	Parameter	[FCPMS] / GMT, LX PSCC	✓	✓	(✓)	(✓)	(✓)
Procedure modules	Main processing	Main-routines	[FCPMS)], …	✓	✓	(✓)	(✓)	(✓)
Contextualisation Scenario	Integration	Hybrid	… / GMT, LX PSCC …	✓	✓	(✓)	(✓)	(✓)
Observer path	Path / project	Line	xyz / GMT, LX PSCC	✓	✓	(✓)	(✓)	(✓)
Observer track	Track / project	Line	xyz / GMT, LX PSCC	✓	✓	(✓)	(✓)	(✓)
AoI	Selection, cut	Area	netCDF, xyz / GMT, LX PSCC	✓	✓	(✓)	(✓)	(✓)
Sampling	Resampling	[Raster]	netCDF / GMT, LX PSCC	✓	✓	(✓)	(✓)	(✓)
Canvas mapping	Basemap	[Mapping]	netCDF / GMT, LX PSCC	✓	✓	(✓)	(✓)	(✓)
Gridding	Grid operations, …	[Grid]	netCDF / GMT, LX PSCC	✓	✓	(✓)	(✓)	(✓)
Illumination	Height	Singular	netCDF / GMT, LX PSCC	✓	✓	(✓)	(✓)	(✓)
Math operations	Calculation	[Algorithm]	… / GMT, LX PSCC	✓	✓	(✓)	(✓)	(✓)
Triangulation	Calculation	[Algorithm]	… / GMT, LX PSCC	✓	✓	(✓)	(✓)	(✓)
Regression	Calculation	[Algorithm]	… / GMT, LX PSCC	✓	✓	(✓)	(✓)	(✓)
Colour	Colourisation	[Sequence]	CPT,/ GMT, LX PSCC	✓	✓	(✓)	(✓)	(✓)
Filtering	Selection, select	[Decimation]	… / GMT, LX PSCC	✓	✓	(✓)	(✓)	(✓)
Movie module	Iteration, …	Parameter	… / GMT, LX PSCC	✓	✓	(✓)	(✓)	(✓)
Proc. of knowledge compl.	Calculation	[Algorithm]	CKRI, PCRE, … / LX PSCC	✓	✓	(✓)	(✓)	(✓)
Spatial proc. of preh. ctxts.	Selection, calculation	[Algorithm]	CKRI, PCRE / GMT, …, LX PSCC	✓	✓	(✓)	(✓)	(✓)
Events	Symbolic, functional	Symb. repr.	CKRI, PCRE / GMT, …, LX PSCC	✓	✓	(✓)	(✓)	(✓)
Arbitary symbols	Symbolic, functional context	Symb. repr.	[vector graphics] / GMT, LX PSCC	✓	✓	(✓)	(✓)	(✓)
Degenerated ellipses	Azimuthal	Area	xyz / GMT, LX PSCC	✓	✓	(✓)	(✓)	(✓)
Range	Azimuthal	Area	xyz / GMT, LX PSCC	✓	✓	(✓)	(✓)	(✓)
Projection	Geospherical, orthographic	[Algorithm]	… / GMT, PROJ, LX PSCC	✓	✓	(✓)	(✓)	(✓)
…	…	…	…	…	…	…	…	…
Resource usage (main proc.)	Main proc., parallelisation	Frame, view	… / OpenMP, GNU parallel, LX PSCC	✓	✓	n.a.	✓	✓
	On-scratch processing	Various	… / OpenMP, GNU parallel, LX PSCC	✓	✓	n.a.	✓	✓
	Model reduction frame, anim.	Various	… / GMT, (LX PSCC)	✓	✓	n.a.	✓	✓
	Live frame control	Various	JPG, PNG, PDF / (LX PSCC)	✓	✓	n.a.	✓	✓
Transform., symbolic repr.	Post-processing, batch	Post-routines	Scales, KML, … / LX PSCC	✓	✓	n.a.	(✓)	(✓)
Visualisation, analysis	Post-processing, interactive	Image, Video	PNG, MP4, … / LX PSCC	✓	✓	n.a.	(✓)	(✓)

Equal Area. The resolution is drastically reduced for use in this publication. Generated representations include integrated CKRI references, projection of topographic and bathymetric results, and further knowledge for respective areas, based on the coherent conceptual knowledge. The frame sequence of symbolic representations enable to contextualise named factual data (CKRI: UDC:551.2…,551.21,550.3,(23);"62" and UDC:167/168…;51… referring to CKRI: UDC:711.…,692,903,902 for 150 km radii) [1].

Major multi-disciplinary results are the shown insights regarding the details of prehistoric settlement infrastructures / Holocene maars for which we find larger numbers of prehistorical settlements were set and used in the volcanic regions Eifel (DE) and Auvergne (FR) areas than in the other areas, all of which can be precisely assigned and further contextualised. Ongoing analysis and discussion of the multitude of resulting historico-cultural meanings will be given in later publications.

B. Discipline's Workflow: Frame Conversion Benchmark

The number of parallel cores used for the making of individual frames can be efficiently controlled. The parallel processing itself does not depend on OpenMP. Table IV gives the dimensions of canvas sizes for an excerpt of common formats, represented by pixel (p) scales. The given formats High Definition (HD), Ultra High Definition (UHD), Ultra Extended Graphics Array (UXGA), Extended Graphics Array (XGA), and Super XGA Plus (SXGA+) are commonly used in resources development and practical high resolution workflows.

TABLE IV. CANVAS SIZES AND FORMATS USED IN PRACTICAL CASE SCENARIO IMPLEMENTATIONS (TABLE II, EXCERPT).

Canvas Size (p)	*Format*	
Format 16:9 (e.g., 24×13.5 cm)		
7680 × 4320	UHD-2	8 k
3840 × 2160	UHD	4 k
1920 × 1080	HD	
Format 4:3 (e.g., 24×18 cm)		
1600 × 1200	UXGA	
1400 × 1050	SXGA+	
1024 × 768	XGA	

The conversion of frames can be done in parallel using GraphicsMagick [25]. GraphicsMagick includes Gnu's Not Unix (GNU) libgomp [26] of the GNU Offloading and Multi-Processing Project (GOMP). Table V shows the frame conversion benchmark results for different canvas sizes as used in the parallel implementations of practical case scenarios. The results compare number of threads, iterations, user time, total time, iterations per second, iterations per CPU, speedup, and Karp-Flatt result. The conversion uses a common 128×128

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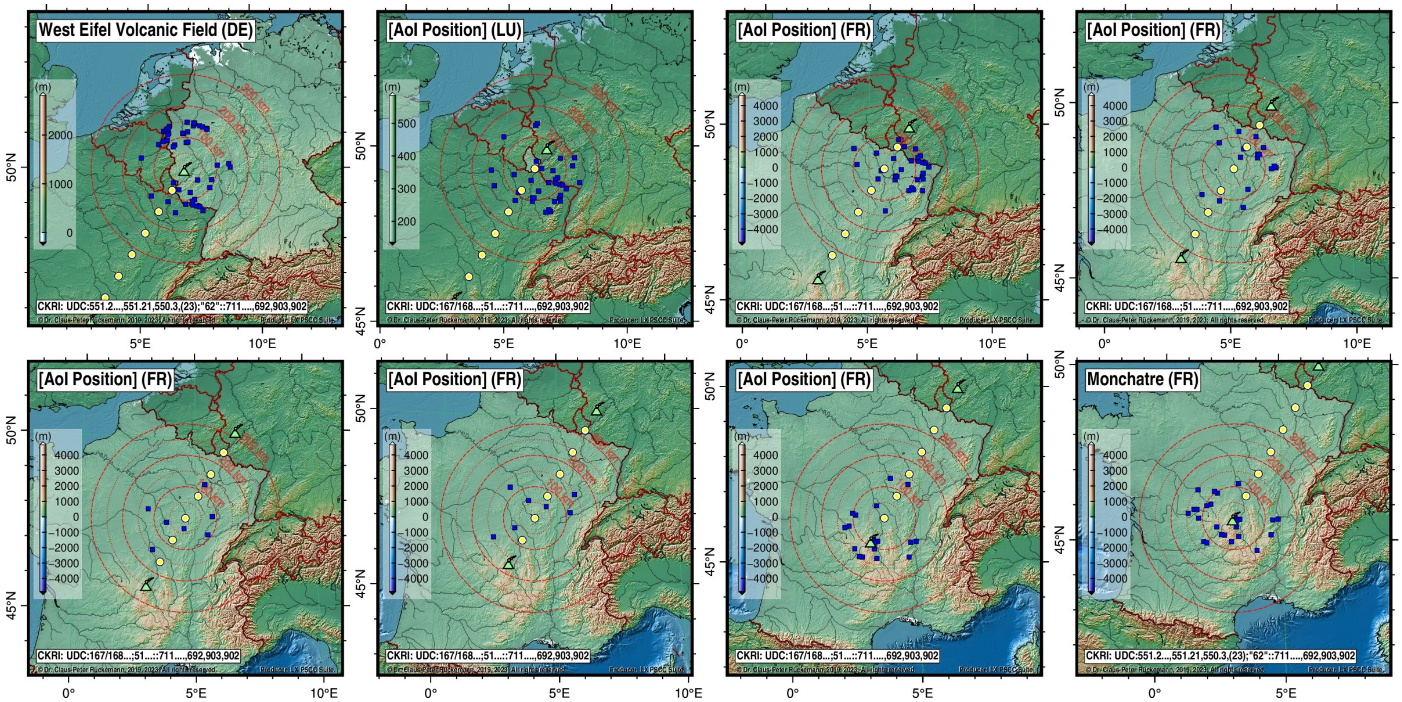

Figure 1. Discipline workflow results of prehistoric settlement infrastructures in factual and historico-cultural chorological and chronological contexts with a volcanological features group (maars, Holocene-historical) and satellite data based on the coherent conceptual knowledge integration and discovery (excerpt).

TABLE V. FRAME CONVERSION BENCHMARK RESULTS FOR CANVAS SIZES USED IN PARALLEL IMPLEMENTATIONS OF PRACTICAL MULTI-DISCIPLINARY CASE SCENARIO WORKFLOWS OF ARCHAEOLOGICAL / PREHISTORICAL CONTEXTUALISATION (TABLE II, EXCERPT).

Threads	*Iterations*	*User Time*	*Elapsed Time*	*Iterations / s*	*Iterations / CPU*	*Speedup*	*Karp-Flatt*
			7680×4320 (UHD-2)				
1	2	10.56 s	10.563899 s	0.189	0.189	1.00	1.000
18	26	138.39 s	10.094287 s	2.576	0.188	13.60	0.019
36	41	220.25 s	10.067891 s	4.072	0.186	21.51	0.019
			3840×2160 (UHD)				
1	8	10.62 s	10.625725 s	0.753	0.753	1.00	1.000
18	104	141.39 s	10.075150 s	10.322	0.736	13.71	0.018
36	166	233.24 s	10.056526 s	16.507	0.712	21.92	0.018
			1024×768 (XGA)				
1	82	10.08 s	10.078310 s	8.136	8.135	1.00	1.000
18	1191	179.99 s	10.007169 s	119.015	6.617	14.63	0.014
36	1856	358.52 s	10.001333 s	185.575	5.177	22.81	0.017

granite texture pattern iteration for standardisation. The benchmark uses the Karp-Flatt metric [27], which is a measure of code parallelisation in parallel processor systems. The resulting implementation is very scalable and can use practical workflow parallelisations from small canvas sizes up to defined sizes even beyond UHD-2. Sizes of UHD are very appropriate for many HR scenarios with commonly available technical infrastructures while being relatively efficient with resources.

V. CONCLUSION

This paper presented the results achieved for the methodological discovery and parallelisation of workflow logic of contextualisation in prehistorical archaeology, based on coherent multi-disciplinary conceptual knowledge. The implemented workflows employed the latest versions of the prehistory-protohistory and archaeology CKRI and the CRI framework. The implemented and realised contextualisation workflows proved efficient, flexible, and sustainable. The presented contexts, entities, and workflow implementations provide solid fact-based fundaments for contextualisation and consequent fact-based historico-cultural interpretation, procedures, which should be deployed by members of the contributing disciplines.

Ongoing, the reference implementations and procedures will be extended for generation of symbolic representation for advanced multi-dimensional knowledge models. Future research will address the creation and further development of the prehistory-protohistory and archaeology CKRI and the CRI framework for coherent multi-disciplinary conceptual contextualisation, enabling multi-disciplinary equal footing with contributions from all scientific disciplines, e.g., natural sciences, soil science, and linguistics, especially supporting new advanced methods in prehistorical archaeology for knowledge integration, contextualisation, and analysis.

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