– Information Science and Inter-disciplinary Long-term Strategies –

Key to Insight, Consistency, and Sustainability: Conceptual Knowledge Reference Methodology Spanning Prehistory, Archaeology, Natural Sciences, and Humanities

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### Epitome: Topic, focus, and goal

- **Topic and focus:** Inter-disciplinary collaboration tasks, integrating disciplines, need special approaches from information science as well as from informatics and technology. Successful integration requires long-term strategies.

- **Goal:** The goal of this tutorial is an advanced understanding of information science, knowledge, and its contexts in scientific, computational, technical, and management disciplines. Information science comprises the fields of collection, documentation, classification, analysis, manipulation, storage, retrieval, movement, dissemination, and protection of information.

- The key to insight, consistency, and sustainability of conceptual knowledge context for day-to-day application is a solid information science fundament. The tutorial presents a consistent and sustainable conceptual knowledge reference methodology and information science implementation, spanning a practical scenario from prehistory and archaeology to natural sciences and humanities.

- This tutorial addresses to all interested users and creators of knowledge and data, in various disciplines, information science, prehistory, archaeology, geosciences, environmental sciences, social and life sciences, as well as to users of advanced applications and providers of resources and services, e.g., library science and High End Computing. There are no special informatics prerequisites or High End Computing experiences necessary to take part in this tutorial.

Citation/reference: [1]
Way (NOT) to go: Knowledge is Created by Instruments, Artificially...

What others do: “Technology can create excellent results with any input and staff.”

Let us take a look on what a virtual, “effective” institution will do.

NUTS’ initiative:
- Hire management, administration, data services, ‘apps’, and excellence is at your hands.

NUTS’ strategy:
- Today, long-term knowledge and research are not relevant anymore.
- Any result can be created artificially.
- All relevant algorithms can automatically be generated.
- The key asset of any science is its market strategy.

NUTS’ results and recommendations:
- Recognise that any past insight and knowledge has shown useless.
- Only invest in the upcoming applications and patches and technical staff.
- Get rid of activities, which mean years of research and dedication.
- Improvement cycles of described procedure need continuous speed up.
Classical, medieval, modern, . . .

Prehistory: ( . . . to archaeology)
⇒ “art” to “technology” but how to understand/contextualise?

Heron of Alexandria: (greek antique, “Steam Ball”)
⇒ “entertainment” but not used as technology.

Isidore of Seville: (encyclopedic, broad documentation)
⇒ end of medieval phase, not further used.

Polyhistor: (Martin Fogel, broad knowledge)
⇒ broad base, not further used.

Last decades / Internet: (knowledge?)
⇒ huge amounts of knowledge lost (besides contrary claims).

In percentage we nearly know nothing about the past.

- Prehistorical, ancient, historical, near past: Realia/contexts are mostly lost.
- Prehistorical, ancient, historical, near past: Documentation is mostly lost.
- Prehistorical, ancient, historical, near past: Technology is not fully understood.
- Context of (past) objects and applications is not available anymore. . . .
Start-up experiences

- Information Science can provide fundamentals and answers.
- Prehistorical ... and many associated information do have/require special context.
- Knowledge should be addressable by ‘holistic’ approaches.
- Cognition based on prehistorical information is special.
- Content and context of said research targets require special methodologies.
- Methodologies need to enable a plethora of implementations.
- Decision Making needs to address knowledge, special content and context.
- ...

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Information Science

Definition

**Information Science**: Information science is the science of information in theory and practice.

Fundaments

*The essential fundaments of information science are information and philosophy.*
Focus

Information science investigates the being of information, information related properties, and information processes.

Information science focuses on theory and methodologies and their application in practice, understanding information related problems, preserving, developing, and making use of information.

Information science primarily tackles systemic problems rather than individual pieces of technology within systems.

Information science comprises . . .

Information science comprises the fields of collection, documentation, classification, analysis, manipulation, storage, retrieval, movement, dissemination, and protection of information.
Information science is associated with psychology, computer science, and technology.

Information science is interlinked with cognitive science, archival science, linguistics, museology, management, mathematics, philosophy, commerce, law, public policy, and social sciences.
Information and communication

Information science deals with any information and communication, e.g.:

- knowledge in organisations,
- interaction between people,
- information systems,
- understanding information systems,
- creating, replacing, improving information systems.
Information Science and the fundament of intrinsically tied complements

- **Episteme:**
  - refers to ‘knowledge’, ‘understanding’, ‘science’.

- **Techne:**
  - “craft”, “art”.

- **Doxa:**
  - from “to appear”, “to seem”, “to accept”, “to think”. 
Knowledge base:

Knowledge transfer is essential.

Over generations of objects and subjects, this requires:

- Knowledge recognition (expertise).
- Knowledge documentation, for any aspect of nature and society (sciences, literature, technical descriptions, tools, cultural heritage, mythology, songs, media, ...).
- Long-term means.
Assets

- Knowledge (factual, conceptual, procedural, metacognitive, …)
- Existing plethora of knowledge and insight.
Fundaments

- The fundamentals of terminology and of understanding knowledge are laid out by Aristotle [2] [3], being an essential part of ‘Ethics’ [4].

- Information science can very much benefit from Aristotle’s fundamentals and a knowledge-centric approach (Anderson and Krathwohl) [5] but for building holistic and sustainable solutions they need to go beyond the available technology-based approaches and hypothesis [6] as analysed in Platons’ Phaidon.

- In consequence, an updated view on the knowledge complements including the creation of interfaces between methods and applications (e.g., based on the methodology of Knowledge Mapping [7]) is addressed in the following excerpts.
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- In consequence, an updated view on the knowledge complements including the creation of interfaces between methods and applications (e.g., based on the methodology of Knowledge Mapping [7]) is addressed in the following excerpts.
The implemented method and the integration modules for result context creation and georeferencing has been a viable, efficient, and flexible solution in many case scenarios. Implementations are far not trivial but any discipline being able to ask questions as demonstrated should also be able to deploy the methodology and presented components for creating solid fundaments and practical solutions for challenging, complex scenarios, e.g., classification and dating of objects [8], geoscientific prospection, surveying [9], and knowledge [10], chorological and chronological context [11], can contribute to the fundaments of archeological and prehistorical cognition [12] and insight [13] regarding realia and abstract objects, knowledge, and contexts. The presented knowledge-based method and conceptual knowledge framework allow to address context very flexibly, e.g., in order to enable the metacognitive documentation of metacognitive and procedural knowledge of Geoscientific Information Systems or Geographic Information System analysis [14], filtering contextualised artistic representations [15] and managing object collections [16]. Knowledge-based approaches can also be beneficial without advanced knowledge resources, e.g., in cases of realia collections, information management and service oriented institutions and research data collection, e.g., The Digital Archaeological Record [17] of Digital Antiquity [18]. For example, in focus cases of archaeology, prehistory, and history context and georeferencing can further be supported by facet creation into more dimensions and also allows the application of a consistent conceptual base for description and fuzziness, beyond common auxiliaries and georeferencing.
Systematical View on Knowledge: FCPM Complements

Complements of Knowledge and Corresponding Sample Implementations:

(Source: Aristotle; Anderson & Krathwohl; SACINAS Delegates’ Summit 2015–2018)

- **Factual Knowledge** ⇔ **Numerical data, data** ...  
  - Conceptual Knowledge ⇔ Classification ...  
  - Procedural Knowledge ⇔ Computing ...  
  - Metacognitive Knowledge ⇔ Experience ...  
  - ...
Complements of Knowledge and Corresponding Sample Implementations:

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- . . .
Best Practice and Definitions Series

- **Knowledge and Computing.**
- **Data-centric and Big Data** – Science, Society, Law, Industry, and Engineering.
- **Data Sciences** – Beyond Statistics.
- **Data Value.**
- **Formalisation.**
- . . .
“Knowledge is created from a subjective combination of different attainments as there are intuition, experience, information, education, decision, power of persuasion and so on, which are selected, compared and balanced against each other, which are transformed, interpreted, and used in reasoning, also to infer further knowledge. Therefore, not all the knowledge can be explicitly formalised. Knowledge and content are multi- and inter-disciplinary long-term targets and values. In practice, powerful and secure information technology can support knowledge-based works and values.”

“Computing means methodologies, technological means, and devices applicable for universal automatic manipulation and processing of data and information. Computing is a practical tool and has well defined purposes and goals.”


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Data-centric and Big Data [20] (Delegates and other contributors)

- "The term data-centric refers to a focus, in which data is most relevant in context with a purpose. Data structuring, data shaping, and long-term aspects are important concerns. Data-centricity concentrates on data-based content and is beneficial for information and knowledge and for emphasizing their value. Technical implementations need to consider distributed data, non-distributed data, and data locality and enable advanced data handling and analysis. Implementations should support separating data from technical implementations as far as possible."

- "The term Big Data refers to data of size and/or complexity at the upper limit of what is currently feasible to be handled with storage and computing installations. Big Data can be structured and unstructured. Data use with associated application scenarios can be categorised by volume, velocity, variability, vitality, veracity, value, etc. Driving forces in context with Big Data are advanced data analysis and insight. Disciplines have to define their ‘currency’ when advancing from Big Data to Value Data."


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“Qualified Data, especially for an enterprise, represents frozen knowledge or in other words frozen value. The abilities to understand and manage these data is what we call data science. Data results from action, hence, data science can be defined secondary to data. The essence of Data Science is to give qualified access to relevant data to owners and users. Hardware and software and their implementation represent the tertiary level of qualified and high level data.”


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Data Value Definition [22] (Delegates and other contributors)

“Data value is the primary ranked value in scenarios comprised of data and computing context. In general, processing of data, is the cause for computing. In consequence, data, including algorithms and other factual, procedural, and further knowledge, have to be ranked primary on the scale of values whereas machinery for processing data, including computing, are providing means of secondary ranked value. In addition, further values, including economic values, can be associated with consecutive deployment of data and machinery.”

This is unaffected by varying views and attributions, including quality. Nevertheless, different views can scale values.

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Formalisation Definition [23] (Delegates and other contributors)

“Formalisation is the process of creating a defined set of rules, allowing a formal system to infer theorems from axioms. Formal systems may represent well-defined systems of abstract thought. Description and analysis of any detail of any more or less complex system and physical background essentially require a formalisation process. The process includes abstraction and reduction of knowledge, keeping the preconditioned importance of respective context. Consequently, formalisation should be created and context observed by educated experts within the respective discipline.”

All mathematical-machine based systems, e.g., computers, are formal systems. Ideologies should be kept outside of formalisation.


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URL: https://doi.org/10.15488/3409 (DOI).
Application scenarios

- Knowledge creation.
- Valorisation.
- Integration.
- ...
Where knowledge is . . .

Knowledge is created from a subjective combination of different attainments as there are intuition, experience, information, education, decision, power of persuasion and so on, which are selected, compared and balanced against each other, which are transformed and interpreted.

And the consequences . . .

Authentic knowledge therefore does not exist, it always has to be enlived again. Knowledge must not be confused with information or data which can be stored. Knowledge cannot be stored nor can it simply exist, neither in the Internet, nor in computers, databases, programs or books.
Processes

- Knowledge base creation,
- Knowledge base transfer over generations,
- Documentation of requirements respective algorithms,
- Documentation of context respective architectures,
- Usage development within tender processes.
Wrong terms can be very persistent:

- Sunrise (earth is flat?),
- Sunset (from dusk till dawn?),
- Malaria (and prejudice – ahead of scientific results?).
- …
Examples

- Depiction, traffic signs and their description different.
- Companies do try critical products in countries with reduced privacy perception.
- Overall personal security will mean insecurity for society.
- Color perception is different by society.

Description

- “Standardisation” and “internationalisation”.
- Foreign word “privacy”.
- Trend for hidden security.
- Words for new colors have been added to languages and perception.
International and other differences

- Privacy perception,
- Different terminology,
- Legal regulations,
- Legal frameworks.
Theory and practice

- Structural deficits.
- Content can be described and even signed to a certain extend.
- Context cannot be handled to a comparable extent. (Users can sign a PDF document, but what about signing it's context?)
- Long-term issues are mostly out of sight. (What will signature validity mean to archiving and reuse?)
- What does this in general mean to long-term knowledge-based processes?
Application scenarios and decision making support

Following case studies show simplified, practical application scenarios for:

- separating essential knowledge (e.g., knowledge resources, structure)
- creating knowledge based components (e.g., Active Source)
- supporting increased decision potential (e.g., UDC classification)
- integrating high end resources (e.g., compute and storage)
Examples for Multi-Disciplinary Use

Multi-disciplinary status excerpts

- Medical informatics,
- Geoinformatics,
- Legal informatics,
- Geoforensics,
- Prehistory, contextualisation, and cognition,
- Archaeology and digital archaeology,
- Medical geology,
- Digital forensics,
- ...
Content, context

- Information on realia is often lost.
- Information on context is often lost, isolated, or scattered.
- Historical sources cannot be used in the vast majority of cases.
- Language-based context is rarely available/preserved.
- Contextualisation is difficult to achieve.
- Cognition and insight require/allow multi-disciplinary approaches.
- Cognition and insight can foster inter-/trans-disciplinary achievements.
- Realia objects often require special precautions and long-term documentation – and are beyond classical written sources.
- All participating disciplines, services, and resources have to be prepared for challenges as big data, critical data, accessibility, longevity, and usability.

... digital and long-term issues

- Even best practice cannot fully preserve realia and data context.
- Context is often destroyed.
- Long-term issues.
- Currently neither a standard being used for one discipline nor an international standard.
Content, context

- Overall information is widely distributed.
- Sometimes very difficult and a long lasting challenge not only to create information but even to get access to a few suitable information sources.
- Digital and realia objects.
- All participating disciplines, services, and resources have to be prepared for challenges as big data, critical data, accessibility, longevity, and usability.

... digital and long-term issues

- Even best practice cannot fully preserve realia and data context.
- Context is often destroyed.
- Long-term issues.
- Currently neither a standard being used for one discipline nor an international standard.
- ...
Prehistory, Archaeology, . . .

Specialties and Goals

- Prehistory – natural sciences, realia sources, logos, . . .
- Archaeology – historical sources, realia sources, . . .
- Need integrated knowledge base for prehistory, archaeology, natural sciences, and humanities.
- Necessary to collect data from central data centers or registers.

Examples prehistorical, archaeological, and geophysical data:
- North American Database of Archaeological Geophysics (NADAG).
- Center for Advanced Spatial Technologies (CAST).
- Archaeology Data Service (ADS).
- Records as with Center of Digital Antiquity.
- Records as with the Digital Archaeological Record (tDAR).

- Knowledge based approaches.
- Integration methodologies (e.g., superordinate knowledge methodologies, “collaboration house” framework) can support many relevant aspects.
... digital and long-term issues

- Documentation.
- Natural sciences data integration?
- Catalogs (International Classification / Catalog of Diseases, ICD).
- Classification (Universal Decimal Classification, UDC).
- Data security.
- Privacy.
- Anonymity.
- ...
digital and long-term issues

- Documentation.
- Catalogues.
- Classification (Universal Decimal Classification, UDC). Today about 150000 libraries are using UDC classification and implementing information systems herewith.
- Referencing.
- Search.
- Licensing.
Basics of Decision Making ("DM")

Decision making is the fundamental base for any process as well as decision making is a process and result itself.

Nevertheless it is very common

- ... to have deficits in decision making processes.
- ... to underestimate the value of knowledge creation.
- ... to have opposition due to historical and social development.

Aware of!

- No decision is an influence to the "selection", too!
- To shorten planned decision making processes means significant interaction.
Lemma 1:

- It is easy to do any decision without expertise.

Lemma 2:

- A decision (making process) should be fast and perfectly correct.

  In case a decision cannot be fast and perfect, it should be fast or perfect.

  In no case should a decision be slow and wrong.
Essential relation:

Decision making! ⇔ Selection making!

Essential complement to decision:

Making a choice!
Application Scenarios
Problem Analysis

Description:
- Performance analysis (current status / resulting status),
- Problem / target identification (e.g., deviations from performance standard, causes, change of distinctive feature),
- Problem / target description,
- Distinguishing marks between what has been effected by a cause and what has not,
- Deduction of causes from relevant changes found with the problem analysis (identification),
- Cause to a problem is most likely the one that exactly explains the sum of facts.
Example Decision Making Process

**Description:**

- Establishing the objectives,
- Classification of objectives,
- Place classified objectives in order of importance,
- Development of alternative actions,
- Evaluation of alternatives against all the objectives,
- The tentative decision is that alternative being is able to achieve all the objectives,
- Evaluation of the tentative decision for possible consequences,
- Take decisive actions, take additional actions (prevent adverse consequences from becoming problems)
- Start problem analysis and decision making process iteratively,
- Steps for decision model in order to determine an optimal production plan and reduce conflict potential.
Description:

For best practice, introduce a decision planning process to important decisions in order to result in the following benefits:

1. **Establish independent goals.**
   That means a conscious and directed series of choices.

2. **Aim to a standard of measurement.**
   The measurement should provide information on the distance to the goal.

3. **Convert values to action.**
   The resulting information should be used to support the planning.

4. **Commit limited resources in an orderly way.**
   Planning and commitments for any kind of resources, e.g., staff, money, time.
Example Decision Making Phases

Phases:

**Orientation stage:** Starting with kick-off or warm-up, exchange with all parties.

**Conflict stage:** Dispute, arguments, working on common denominators and positions.

**Emergence stage:** Vague positions and opinions being discussed.

**Reinforcement stage:** Decision making and justification.
Selected Decision Making Techniques

Techniques:

Rational decision making: List the pros and cons (advantages and disadvantages) of each option. Contrast the costs and benefits of alternatives.

Elimination by aspects: Choosing alternatives by “mathematical psychology”. Covert elimination process, comparing the available alternatives by aspects. Choose an aspect and eliminate the alternatives without the aspect. Repeat until one alternative remains.

Simple prioritisation: Choosing an alternative showing the highest probability-weighted utility from all alternatives, resulting from the decision analysis process.

Satisficing: The examination of alternatives is stopped as soon as an acceptable alternative is found.
Instruments, factual, conceptual, procedural, ...

- Knowledge Resources, ...
- Universal Decimal Classification (UDC), ...
- Unified Modeling Language (UML), ...
- High End Computing (HEC), ...
- Open Archives Initiative (OAI) and OAI-Protocol for Metadata Harvesting (OAI-PMH), ...
- ...

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**Universal Decimal Classification (UDC)**

The Universal Decimal Classification (UDC) is a general plan for the knowledge classification. UDC is a hierarchical decimal classification system that divides the main knowledge fields into 10 main categories (numbered from 0 to 9). Each field is in turn divided into 10 subfields, each subfield is in turn divided into 10 subsubfields, and so on. A more extensive classification code in general describes a more specific subject.

**Faceted and multi-disciplinary context**

“Facetted” and “multi-disciplinary” is synonym to the Universal Decimal Classification (UDC), [http://www.udcc.org](http://www.udcc.org). UDC uses a “(...)” notation in order to indicate aspect. These descriptions are called facets. In multi-disciplinary object context a faceted classification does provide advantages over enumerative concepts. The classification deployed for a universal documentation must be able to describe any object with any relation, structure, and level of detail. Objects include any media, textual documents, illustrations, photos, maps, videos, sound recordings, as well as realia, physical objects such as museum objects.
Contributions, components, and resources

- The Universal Decimal Classification (UDC) [24] is the world’s foremost document indexing language in the form of a multi-lingual classification scheme covering all fields of knowledge and constitutes a sophisticated indexing and retrieval tool. The UDC is designed for subject description and indexing of content of information resources irrespective of the carrier, form, format, and language. UDC is an analytic-synthetic and facetted classification.

- UDC schedules are organised as a coherent system of knowledge with associative relationships and references between concepts and related fields.

- UDC-based references in this publication are taken from the multi-lingual UDC summary [24] released by the UDC Consortium (Creative Commons lic.) [25].

- Facets can be created with any auxiliary tables. Means to achieve overall efficient realisations, even for complex scenarios: Principles of Superordinate Knowledge, integrating arbitrary knowledge. Core assembly elements of Superordinate Knowledge are methodology, implementation, and realisation [26].

- Comprehensive focussed subsets of conceptual knowledge provide excellent modular, standardised complements for information systems component impl., e.g., environmental information management & computation [27].

- Following references' excerpts from The Prehistory and Archaeology Knowledge Archive (PAKA), DIMF, 2020.
<table>
<thead>
<tr>
<th>Code / Sign Ref.</th>
<th>Verbal Description (EN)</th>
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</thead>
<tbody>
<tr>
<td>UDC:1</td>
<td>Philosophy. Psychology</td>
</tr>
<tr>
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<td>Religion. Theology</td>
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<tr>
<td>UDC:3</td>
<td>Social Sciences</td>
</tr>
<tr>
<td>UDC:5</td>
<td>Mathematics. Natural Sciences</td>
</tr>
<tr>
<td>UDC:6</td>
<td>Applied Sciences. Medicine, Technology</td>
</tr>
<tr>
<td>UDC:7</td>
<td>The Arts. Entertainment. Sport</td>
</tr>
<tr>
<td>UDC:8</td>
<td>Linguistics. Literature</td>
</tr>
<tr>
<td>UDC:9</td>
<td>Geography. Biography. History</td>
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## Conceptual knowledge references: Computer science and technology (EN, excerpt)

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<td>Computer hardware</td>
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<td>Processing units. Processing circuits</td>
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<tr>
<td>UDC:004.33</td>
<td>Memory units. Storage units</td>
</tr>
<tr>
<td>UDC:004.382.2</td>
<td>Supercomputers</td>
</tr>
<tr>
<td>UDC:004.4</td>
<td>Software</td>
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<td>UDC:004.414</td>
<td>Definition phase of system and software engineering</td>
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<tr>
<td>UDC:004.414.2</td>
<td>Computer system analysis and design</td>
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<tr>
<td>UDC:004.414.3</td>
<td>Software requirements analysis</td>
</tr>
<tr>
<td>UDC:004.415</td>
<td>Development phase of system and software engineering</td>
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<td>UDC:004.415.5</td>
<td>Software quality assurance</td>
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<tr>
<td>UDC:004.416</td>
<td>System and software maintenance</td>
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<td>UDC:004.42</td>
<td>Computer programming</td>
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<td>UDC:004.423</td>
<td>Syntax and semantics of programs</td>
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<td>UDC:004.43</td>
<td>Computer languages</td>
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<td>UDC:004.43.C</td>
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<td>UDC:004.43.C++</td>
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<tr>
<td>UDC:004.43.FOR</td>
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<td>UDC:004.431</td>
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<tr>
<td>UDC:004.432</td>
<td>High level languages</td>
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<td>UDC:004.451</td>
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<td>UDC:004.62</td>
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<td>UDC:004.7</td>
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<tr>
<td>UDC:004.71</td>
<td>Computer communication hardware</td>
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<tr>
<td>UDC:004.738.5</td>
<td>Internet</td>
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<tr>
<td>UDC:004.774</td>
<td>HTTP application. World Wide Web in the strict sense. Web resources / content</td>
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<td>UDC:004.82</td>
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<tr>
<td>UDC:004.89</td>
<td>Artificial intelligence application systems. Intelligent knowledge-based systems</td>
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<tr>
<td>UDC:004.932</td>
<td>Image processing</td>
</tr>
<tr>
<td>UDC:004.94</td>
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### Conceptual knowledge references: Archaeology, prehistory, ... (EN, excerpt) [29]

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<td>UDC:903</td>
<td>Prehistory. Prehistoric remains, artefacts, antiquities</td>
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<tr>
<td>UDC:904</td>
<td>Cultural remains of historical times</td>
</tr>
<tr>
<td>UDC:908</td>
<td>Area studies. Study of a locality</td>
</tr>
<tr>
<td>UDC:91</td>
<td>Geography. Exploration of the Earth and of individual countries. Travel. Regional geography</td>
</tr>
<tr>
<td>UDC:912</td>
<td>Nonliterary, nontextual representations of a region</td>
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<tr>
<td>UDC:92</td>
<td>Biographical studies. Genealogy. Heraldry. Flags</td>
</tr>
<tr>
<td>UDC:93/94</td>
<td>History</td>
</tr>
<tr>
<td>UDC:94</td>
<td>General history</td>
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</table>
Instruments

Conceptual Knowledge References: Mathematics and Natural Sciences

Conceptual knowledge references: Mathematics, natural sciences (EN, excerpt) [30]

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<thead>
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<tr>
<td>UDC:51</td>
<td>Mathematics</td>
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<tr>
<td>UDC:52</td>
<td>Astronomy. Astrophysics. Space research. Geodesy</td>
</tr>
<tr>
<td>UDC:53</td>
<td>Physics</td>
</tr>
<tr>
<td>UDC:54</td>
<td>Chemistry. Crystallography. Mineralogy</td>
</tr>
<tr>
<td>UDC:55</td>
<td>Earth Sciences. Geological sciences</td>
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<tr>
<td>UDC:550.3</td>
<td>Geophysics</td>
</tr>
<tr>
<td>UDC:551.7</td>
<td>Historical geology. Stratigraphy. Palaeogeography</td>
</tr>
<tr>
<td>UDC:551.8</td>
<td>Palaeogeography</td>
</tr>
<tr>
<td>UDC:551.24</td>
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<tr>
<td>UDC:56</td>
<td>Palaeontology</td>
</tr>
<tr>
<td>UDC:57</td>
<td>Biological sciences in general</td>
</tr>
<tr>
<td>UDC:58</td>
<td>Botany</td>
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<tr>
<td>UDC:59</td>
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## Conceptual knowledge references: Auxiliaries of time (EN, excerpt) [31]

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<th>Verbal Description (EN)</th>
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<tbody>
<tr>
<td>UDC: “0”</td>
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</tr>
<tr>
<td>UDC: “1”</td>
<td>Second millennium CE</td>
</tr>
<tr>
<td>UDC: “2”</td>
<td>Third millennium CE</td>
</tr>
<tr>
<td>UDC: “3/7”</td>
<td>Time divisions other than dates in Christian (Gregorian) reckoning</td>
</tr>
<tr>
<td>UDC: “3”</td>
<td>Conventional time divisions and subdivisions: numbered, named, etc.</td>
</tr>
<tr>
<td>UDC: “6”</td>
<td>Geological, archaeological and cultural time divisions</td>
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<tr>
<td>UDC: “61/62”</td>
<td>Geological time division. Geochronology</td>
</tr>
<tr>
<td>UDC: “61”</td>
<td>Precambrian (more than 542 MYBP) (supereon)</td>
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<tr>
<td>UDC: “62”</td>
<td>Phanerozoic (542 MYBP to present) (eon)</td>
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<tr>
<td>UDC: “621”</td>
<td>Palaeozoic / Paleozoic (542-251 MYBP) (era)</td>
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<tr>
<td>UDC: “622”</td>
<td>Mesozoic (251-65.5 MYBP) (era)</td>
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<tr>
<td>UDC: “628”</td>
<td>Cenozoic (65.5 MYBP to present) (era)</td>
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<tr>
<td>UDC: “63”</td>
<td>Archaeological, prehistoric, protohistoric periods and ages</td>
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<tr>
<td>UDC: “67/69”</td>
<td>Time reckonings: universal, secular, non-Christian religious</td>
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<tr>
<td>UDC: “67”</td>
<td>Universal time reckoning. Before Present</td>
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<tr>
<td>UDC: “68”</td>
<td>Secular time reckonings other than universal and the Christian (Gregorian) calendar</td>
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<tr>
<td>UDC: “69”</td>
<td>Dates and time units in non-Christian (non-Gregorian) religious time reckonings</td>
</tr>
<tr>
<td>UDC: “7”</td>
<td>Phenomena in time. Phenomenology of time</td>
</tr>
<tr>
<td>Code / Sign Ref.</td>
<td>Verbal Description (EN)</td>
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<td>-------------------------</td>
</tr>
<tr>
<td>UDC:(1)</td>
<td>Place and space in general. Localization. Orientation</td>
</tr>
<tr>
<td>UDC:(2)</td>
<td>Physiographic designation</td>
</tr>
<tr>
<td>UDC:(3)</td>
<td>Places of the ancient and mediaeval world</td>
</tr>
<tr>
<td>UDC:(31)</td>
<td>Ancient China and Japan</td>
</tr>
<tr>
<td>UDC:(32)</td>
<td>Ancient Egypt</td>
</tr>
<tr>
<td>UDC:(33)</td>
<td>Ancient Roman Province of Judaea. The Holy Land. Region of the Israelites</td>
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<tr>
<td>UDC:(34)</td>
<td>Ancient India</td>
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<td>UDC:(35)</td>
<td>Medo-Persia</td>
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<tr>
<td>UDC:(36)</td>
<td>Regions of the so-called barbarians</td>
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<tr>
<td>UDC:(37)</td>
<td>Italia. Ancient Rome and Italy</td>
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<td>UDC:(38)</td>
<td>Ancient Greece</td>
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<tr>
<td>UDC:(399)</td>
<td>Other regions. Ancient geographical divisions other than those of classical antiquity</td>
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<tr>
<td>UDC:(4)</td>
<td>Europe</td>
</tr>
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<td>UDC:(5)</td>
<td>Asia</td>
</tr>
<tr>
<td>UDC:(6)</td>
<td>Africa</td>
</tr>
<tr>
<td>UDC:(7)</td>
<td>North and Central America</td>
</tr>
<tr>
<td>UDC:(8)</td>
<td>South America</td>
</tr>
<tr>
<td>UDC:(9)</td>
<td>States and regions of the South Pacific and Australia. Arctic. Antarctic</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Code / Sign Ref.</th>
<th>Verbal Description (EN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UDC:(1/9)</td>
<td>Common auxiliaries of place.</td>
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<tr>
<td>UDC:(1)</td>
<td>Place and space in general. Localization. Orientation</td>
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<tr>
<td>UDC:(100)</td>
<td>Universal as to place. International. All countries in general</td>
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<tr>
<td>UDC:(1-0/-9)</td>
<td>Special auxiliary subdivision for boundaries and spatial forms of various kinds</td>
</tr>
<tr>
<td>UDC:(1-0)</td>
<td>Zones</td>
</tr>
<tr>
<td>UDC:(1-1)</td>
<td>Orientation. Points of the compass. Relative position</td>
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<tr>
<td>UDC:(1-2)</td>
<td>Lowest administrative units. Localities</td>
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<tr>
<td>UDC:(1-3)</td>
<td>Larger unit within the state</td>
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<tr>
<td>UDC:(1-4)</td>
<td>Units of highest (state) level. Nations. States. Confederations</td>
</tr>
<tr>
<td>UDC:(1-5)</td>
<td>Dependent or semi-dependent territories</td>
</tr>
<tr>
<td>UDC:(1-6)</td>
<td>States or groupings of states from various points of view</td>
</tr>
<tr>
<td>UDC:(1-7)</td>
<td>Places and areas according to privacy, publicness and other special features</td>
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<tr>
<td>UDC:(1-8)</td>
<td>Location. Source. Transit. Destination</td>
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<tr>
<td>UDC:(1-9)</td>
<td>Regionalization according to specialized points of view</td>
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### Conceptual knowledge references: Physiographic designation (EN, excerpt)

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<td>UDC:(21)</td>
<td>Surface of the Earth in general. Land areas in particular. Natural zones and regions</td>
</tr>
<tr>
<td>UDC:(23)</td>
<td>Above sea level. Surface relief. Above ground generally. Mountains</td>
</tr>
<tr>
<td>UDC:(24)</td>
<td>Below sea level. Underground. Subterranean</td>
</tr>
<tr>
<td>UDC:(25)</td>
<td>Natural flat ground (at, above or below sea level). The ground in its natural condition, cultivated or inhabited</td>
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<tr>
<td>UDC:(26)</td>
<td>Oceans, seas and interconnections</td>
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<tr>
<td>UDC:(28)</td>
<td>Inland waters</td>
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<tr>
<td>UDC:(29)</td>
<td>The world according to physiographic features</td>
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<tr>
<td>UDC:(3/9)</td>
<td>Individual places of the ancient and modern world</td>
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<tr>
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<td>Documents according to physical, external form</td>
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<tr>
<td>UDC:(0.03)</td>
<td>Documents according to method of production</td>
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<td>UDC:(0.034)</td>
<td>Machine-readable documents</td>
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<tr>
<td>UDC:(0.04)</td>
<td>Documents according to stage of production</td>
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<td>UDC:(0.05)</td>
<td>Documents for particular kinds of user</td>
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<tr>
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<td>Documents according to level of presentation and availability</td>
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<tr>
<td>UDC:(0.08)</td>
<td>Separately issued supplements or parts of documents</td>
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<td>UDC:(0.042)</td>
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<td>UDC:=92</td>
<td>Artificial languages for use among human beings. Int. aux. languages (interlanguages)</td>
</tr>
<tr>
<td>UDC:=93</td>
<td>Artificial languages used to instruct machines. Programming/computer languages</td>
</tr>
</tbody>
</table>
UDC Operations

Standardised operations with UDC are, e.g.,

<table>
<thead>
<tr>
<th>Operation</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addition</td>
<td>“+”</td>
</tr>
<tr>
<td>Consecutive extension</td>
<td>“/”</td>
</tr>
<tr>
<td>Relation</td>
<td>“:”</td>
</tr>
<tr>
<td>Subgrouping</td>
<td>“[]”</td>
</tr>
<tr>
<td>Non-UDC notation</td>
<td>“*”</td>
</tr>
<tr>
<td>Alphabetic extension</td>
<td>“A-Z”</td>
</tr>
</tbody>
</table>

besides place, time, nationality, language, form, and characteristics.

Examples

1  (0.02/.08) Special auxiliary subdivision for document form
2  =1/=8  Natural languages
3  =1/=2  Indo-European languages
4  =9/=93  Artificial languages
5  59+636  Zoology and animal breeding
6  (7):(4) Europe referring to America
7  311:[622+669](485) statistics of mining and metallurgy in Sweden
8  004.382.2:[902+550.8] CPR Supercomputers ref. to archaeology and geosciences, CPR author
**Conceptual Knowledge Forks Diagram**

<table>
<thead>
<tr>
<th>Code / Sign Ref.</th>
<th>Verbal Description (EN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UDC:5</td>
<td>Mathematics and natural sciences</td>
</tr>
<tr>
<td>UDC:51</td>
<td>Mathematics</td>
</tr>
<tr>
<td>UDC:53</td>
<td>Physics</td>
</tr>
<tr>
<td>UDC:55</td>
<td>Earth Sciences. Geological sciences</td>
</tr>
<tr>
<td>UDC:550</td>
<td>Earth sciences</td>
</tr>
<tr>
<td>UDC:550.3</td>
<td>Geophysics</td>
</tr>
<tr>
<td>UDC:550.34</td>
<td>Seismology. Earthquakes in general</td>
</tr>
<tr>
<td>UDC:551.2</td>
<td>Internal geodynamics (endogenous processes)</td>
</tr>
<tr>
<td>UDC:551.24</td>
<td>Geotectonics</td>
</tr>
<tr>
<td>UDC:9</td>
<td>Geography. Biography. History</td>
</tr>
<tr>
<td>UDC:902</td>
<td>Archaeology</td>
</tr>
<tr>
<td>UDC:903</td>
<td>Prehistory. Prehistoric remains, artefacts, antiquities</td>
</tr>
<tr>
<td>UDC:904</td>
<td>Cultural remains of historical times</td>
</tr>
</tbody>
</table>

(a) Relevant UDC references for entity groups 5 and 9 (excerpts).

(b) Primary, decimal (UDC) conceptual knowledge forks diagram (excerpt).

**Figure**: Conceptual Knowledge Pattern Matching: (a) relevant UDC reference implementations ([24]) and (b) respective matching process, illustrating discovery paths in the decimally organised structure of conceptual knowledge, starting with main tables.
Multi-line case

A different kind of complexity is what we commonly face in context of knowledge resources, same task and still with arbitrary length and arbitrary number of objects and entities with multi-line formatting to be preserved.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nisyros</strong></td>
<td>[Volcanology, Geology]: Volcano, Type: Strato volcano, Island. Status: Historical, Summit Elevation: 698\UD{m}. VNUM: 0102-05=, ..., Craters: ..., ...</td>
</tr>
<tr>
<td></td>
<td>%I ML: UDC: [550.3],[930.85],[911.2] %I ML: media:...{UDC: [550.3+551.21],<a href="4+38+23">911.2</a>}...jpg Stefanos Crater, Nisyros, Greece. LATLON: 36.578345,27.1680696 %I ML: GoogleMapsLocation: <a href="https://www.google.com/...@36.578345,27.1680696,337m/">https://www.google.com/...@36.578345,27.1680696,337m/</a>... Little Polyvotis Crater, Nisyros, Greece. LATLON: 36.5834105,27.1660736 ...</td>
</tr>
</tbody>
</table>

Knowledge resources’ object (‘Nisyros’): Multi-line formatting, conceptual knowledge, media object entities, and georeferences (excerpt).
Unified Modeling Language (UML)

The Unified Modeling Language (UML) can be used for various purposes with information sciences, software development, and even independent from information sciences, e.g. in economics and business context:

- “business model”
- classes
- messages, objects in their timing sequence
  - coarse overview
  - dynamic
  - parallel processes
  - distributed systems
UML Diagrams

- Use-case diagram
- Class diagram
- Package diagram
- Interaction diagram
- State diagram
- Activity diagram
- Implementation diagram
**Use-case diagram**

Diagram: Use-Case

Phase: Requirements, predefinition, application design – building, delivery

Operational area: business processes, common

**Class diagram**

Diagram: class diagram

Phase: predefinition, application design – building

Operational area: anywhere, the class diagram is the most important UML diagram.

**Package diagram**

Diagram: package diagram

Phase: application design – building

Operational area: overall orientation purposes, which classes in which modules. partitioning into sub-projects, libraries, translation units.
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**Diagram:** Use-Case  
**Phase:** Requirements, predefinition, application design – building, delivery  
**Operational area:** business processes, common

**Class diagram**

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### Package diagram

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**Operational area:** Overall orientation purposes, which classes in which modules. Partitioning into sub-projects, libraries, translation units.
Interaction diagram

Diagram: interaction diagram

Phase: Requirements, predefinition, application design – building, delivery

Operational area: shows the message flow and therefore the cooperation of objects in timing sequence.

Special interaction diagrams are:
  - Sequence diagram: timing call structure with few classes.
  - Collaboration diagram: timing call structure with few messages.

State diagram

Diagram: state diagram

Phase: Requirements, predefinition, application design – building, delivery

Operational area: presentation of dynamical behaviour
Interaction diagram

Diagram: interaction diagram
Phase: Requirements, predefinition, application design – building, delivery
Operational area: shows the message flow and therefore the cooperation of objects in timing sequence.

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Operational area: presentation of dynamical behaviour
Activity diagram and Implementation Diagram

**Activity diagram**

- **Diagram:** activity diagram
- **Phase:** predefinition, application design – building
- **Operational area:** various purposes.

**Implementation diagram**

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- **Phase:** predefinition, application design – building, delivery
- **Operational area:** especially for presentation of distributed applications and components; in general: presentation of implementation aspects (translations units, executable programs, hardware structure)

Special implementation diagrams are:
- component diagram: coherence of software.
- deployment diagram: hardware structure.
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Special implementation diagrams are:

- component diagram: coherence of software.
- deployment diagram: hardware structure.
Basics and prerequisites

- Real goals. Define the goals, different views.
- Need for basic understanding and knowledge base for HEC.
- Prominent HEC and collaboration aspects decision making processes are necessary for.
- Separate the topics (disciplines, resources, ...).
- Gather the real requirements for the analysis.
- Up-to-date resource policies in theory and practice.
- Interesting fields of application are processes within disciplines.
- Future deployment of integration and classification with components of complex systems.
Components (all areas, no sort order):

- Architecture,
- Operating System,
- Applications,
- Programming languages,
- Tools,
- System modeling,
- Vendors,
- Strategy,
- Targets,
- Staff,
- Operation,
- Services,
- System management,
- Complex licensing,
- Policies,
- Governance,
- …
Components (all areas, no sort order):

- Components (all areas) with strong focus on
- Applicability, efficiency,
- Architecture applicability,
- Operating System applicability,
- Efficient applications,
- Programming languages,
- Tools,
- System modeling,
- Vendors,
- Strategy,
- Targets,
- Staff,
- Operation,
- Services,
- System management,
- Complex licensing,
- Policies,
- Governance,
- ...
Process fundamentals:

- Knowledge and experience are more important than hierarchy.
- Find the essential information.
- Rational problem analysis and decision planning.
- Add forensics to all possible information.
- The decision making process needs to define the focus.
- The decision making process needs to define goals.
- There should be only one final instance for selection processes.
- Multiple views for a process must be allowed and supported.
- Define results.
- Define service and responsibilities.
- List requirements and parts.
- Tools are needed for making the selection.
- Keep the tools simple.
- Best practice should be used in order to support the process.
Essential aspects:

- Dissemination.
- Scientific research and consultancy.
- Service and operation.
- Transparency for legal issues.
- Written definition of goals, acknowledged by all parties.
- Quality of Data counts, aware of long-term usage.
- Support structuring the application scenarios with architecture/disciplines.
- Support essential knowledge to be long-term persistent (structure, UDC, OEN, CEN, ...).
- Try to support dynamical application scenarios.
- Acknowledge that for some party prestige and presentation might be an aspect with any system.
Decision on:

- User (scientific and industry) requirements,
- Content,
- Context,
- Operation lifecycle,
- Staff and operation,
- Services,
- Architecture (specification, networks),
- Policies,
- Goals (of the system/service),
- Dissemination,
- (Funding).
Instruments and Obstacles

Obstacles reducing success and efficiency with the processes

- Time consumption (e.g., staff, project timelines),
- Documentation (e.g., low percentage of reusability),
- Classification (e.g., limited views),
- Tools (e.g., changing repeatedly),
- “Standards” (e.g., changing repeatedly),
- ...
- Different perception of goals, strategies, and completeness.
### Structure
- Must be able to contain and refer to any content.

### Full text and keywords
- Groups, regular expressions, search functions, ...

### Soundex
- Algorithm for calculating codes from text strings, representing phonetic properties.
- Originally only used for names, in English.
- The original algorithm mainly encodes consonants.
- Goal is to encode homophones with the same representation, minor spelling differences do result in the same representation.
- Various modifications for any language, topics, any kind of words, support for many programming environments.
- ...

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Staff and resources

- Quantity of Staff and Resources depends.
- ‘Quality’ of Data (QoD) can optimise requirements for staff and resources.
Lessons learned:

- Prehistory and geosciences, natural sciences, humanities: Conceptual knowledge approaches enable sustainable long-term knowledge development and integration.
- Universal context documentation (multi-disciplinary context, multi-lingual, attribution, time, space, relocation, ...).
  - Improve long-term creation of knowledge complements.
  - Provide consistency due to edition practice.
  - Improve factual ‘Quality’ of Data.
  - Foster the use of universal conceptual knowledge framework implementations for multi- and inter-disciplinary research.
  - Foster the creation and application of best practice.
  - Create knowledge-centric, modular implementations.
  - Enable contextualisation and cognitive insight: Create and provide instruments based on knowledge-based standards.
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Information Science and inter-disciplinary long-term strategies

- Foster insight, consistency, sustainability.
- Deploy logic/logos.
- Conceptual knowledge references.
- Scientific research, fundamental, epistemological background.
- Disciplines providing a higher potential of creating insight from multi-disciplinary scientific research can gather even greater benefits – prehistory, archaeology, natural sciences, humanities.

Knowledge complements are the assets of information science!

Applications:

Provide solutions to application scenarios!

Instruments:

Provide fundamentals for creating instruments!
Thank you for your attention!
Reference section containing cited references.


References


References

Post-Summit Results, Delegates’ Summit: Best Practice and Definitions of Data Value, September 13, 2018, The Eighth Symposium on Advanced Computation and Information in Natural and Applied Sciences (SACINAS), The 16th International Conference of Numerical Analysis and Applied Mathematics (ICNAAM), September 13–18, 2018, Rhodes, Greece, 2018, delegates and other contributors: Claus-Peter Rückemann, Westfälische Wilhelms-Universität Münster (WWU) / Knowledge in Motion, Unabhängiges Deutsches Institut für Multi-disziplinäre Forschung (DIMF) / Leibniz Universität Hannover / North-German Supercomputing Alliance (HLRN), Germany; Raffaella Pavani, Department of Mathematics, Politecnico di Milano, Italy; Lutz Schubert, IOMI, University of Ulm, Germany; Birgit Gersbeck-Schierholz, Knowledge in Motion, Unabhängiges Deutsches Institut für Multi-disziplinäre Forschung (DIMF), Germany; Friedrich Hülsmann, Knowledge in Motion, Unabhängiges Deutsches Institut für Multi-disziplinäre Forschung (DIMF), Germany; Lau, Olaf, Knowledge in Motion, Unabhängiges Deutsches Institut für Multi-disziplinäre Forschung (DIMF), Germany; Hofmeister, Martin, Knowledge in Motion, Unabhängiges Deutsches Institut für Multi-disziplinäre Forschung (DIMF), Germany; DOI: 10.15488/3639, URL: http://history.icnaam.org/icnaam_2018/icnaam.org/sites/default/files/Preliminary%20Program%20of%20ICNAAM%202018_web_version_70.pdf, URL: http://icnaam.org/sites/default/files/Preliminary%20Program%20of%20ICNAAM%202018_ver_70.pdf, URL: http://www.user.uni-hannover.de/cpr/x/publ/2018/delegatessummit2018/rueckemann_icnaam2018_summit_summary.pdf, URL:


