Optimization Algorithms in AEC-AI 4.0 Industry

Carlos H. Maureira

PhD. Cellular and Molecular Neuroscience, UCh
MSc. & PhD(c) Computer Science, PUCV

Profiles UPLA

Research Developing Integrated Framework Using AI: IOSF

- Thematic talk on the requested topic profile
- Relate to research interest/specialization
- Some results already published, see references for further details

Num.6: Programming, Software Development, AI

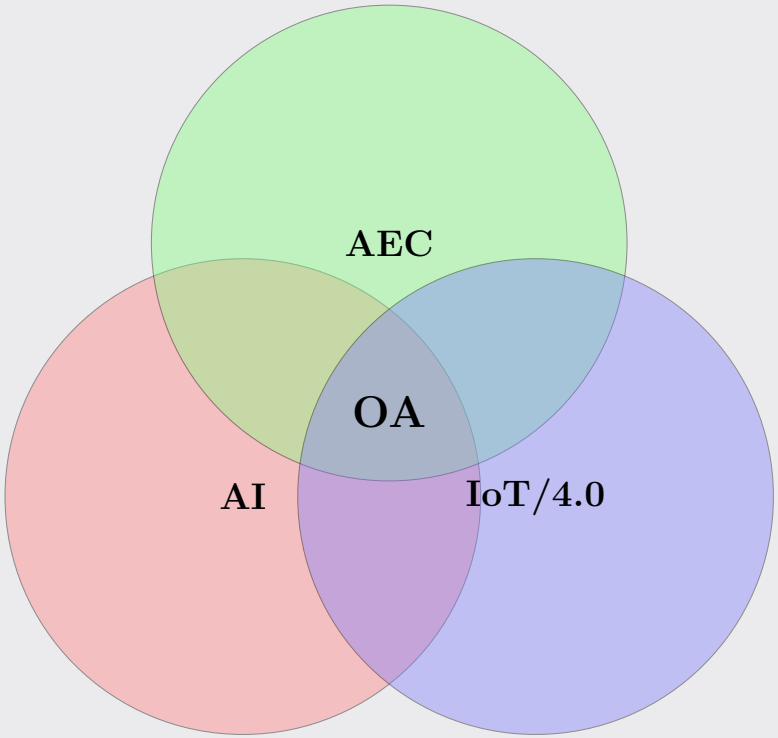
- IOSF for AEC-AI 4.0 Industry
- Macro, Meso and Microscopic levels
- Python and R code

Num.7: Databases, Data Science, Distributed Systems

- LLM Strategies
- Knowledge Domain Organization
- Federated Learning

Three Main Research Fields
Complex Dynamical Subjects

What is at the center?



Interacting areas for the future

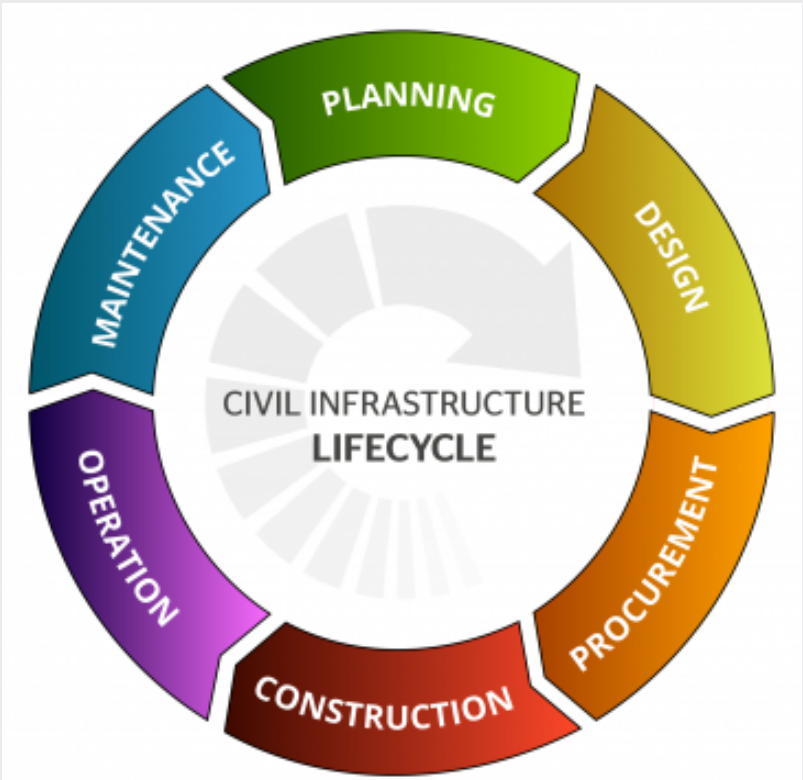
- AEC Sector
- Another Technological Revolution
- The tech sector for a New Era

Lets tray multi-level approach with:

- KE & KDO, and Meta-Methods.

Building Lifecycle[1]
Many components and processes

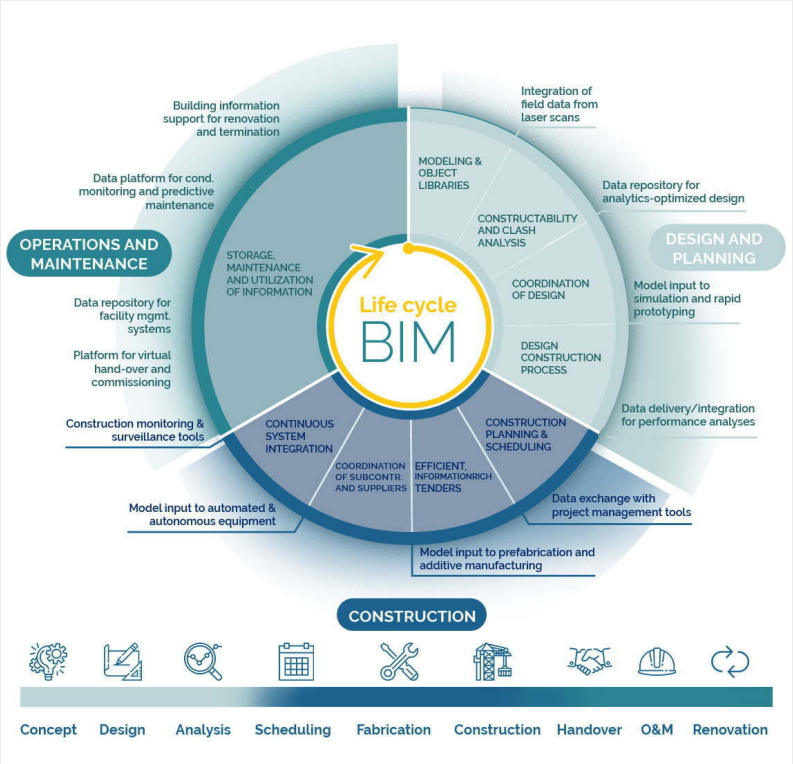
Civil Infrestructure



[1] Yitmen2021; WOS:000890090000001; Altohami2021.

AEC's Technological Backbone[2]

Building Information Modeling



BIM

- CAD-xD
- Standards
- Specifications

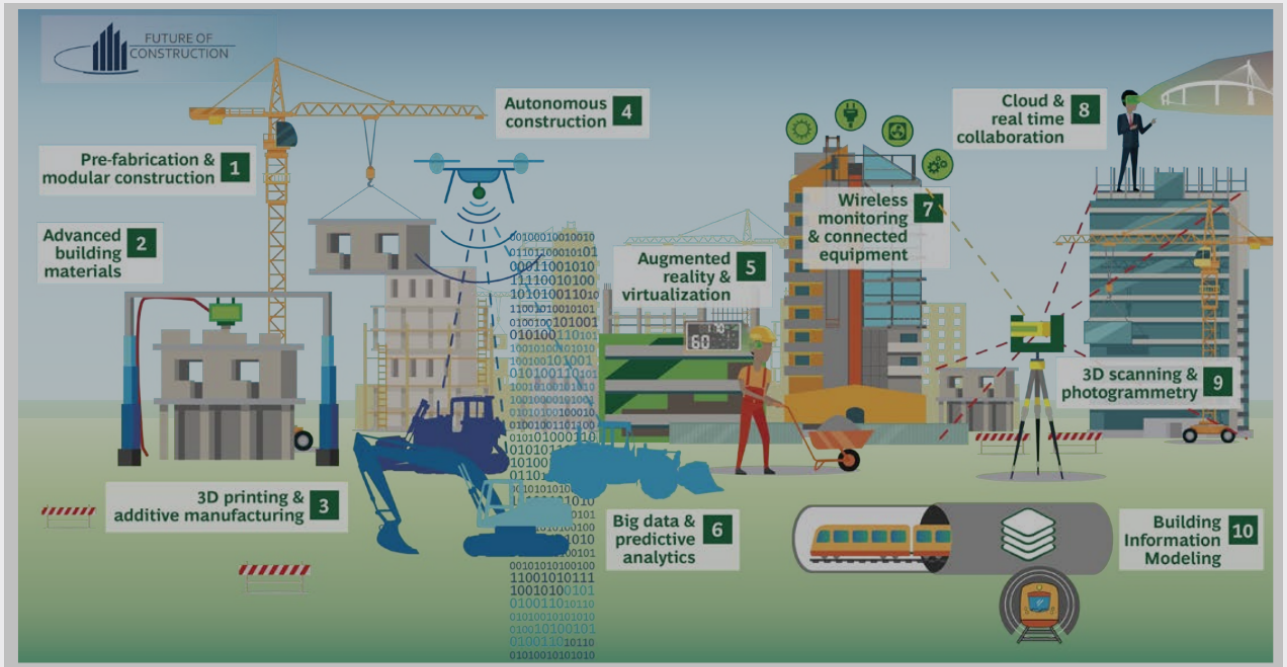
[2] Tang2019.

Computer Vision

[3] Hou2021.

Challenges in Digital Transformation[4]
Economic Perspectives

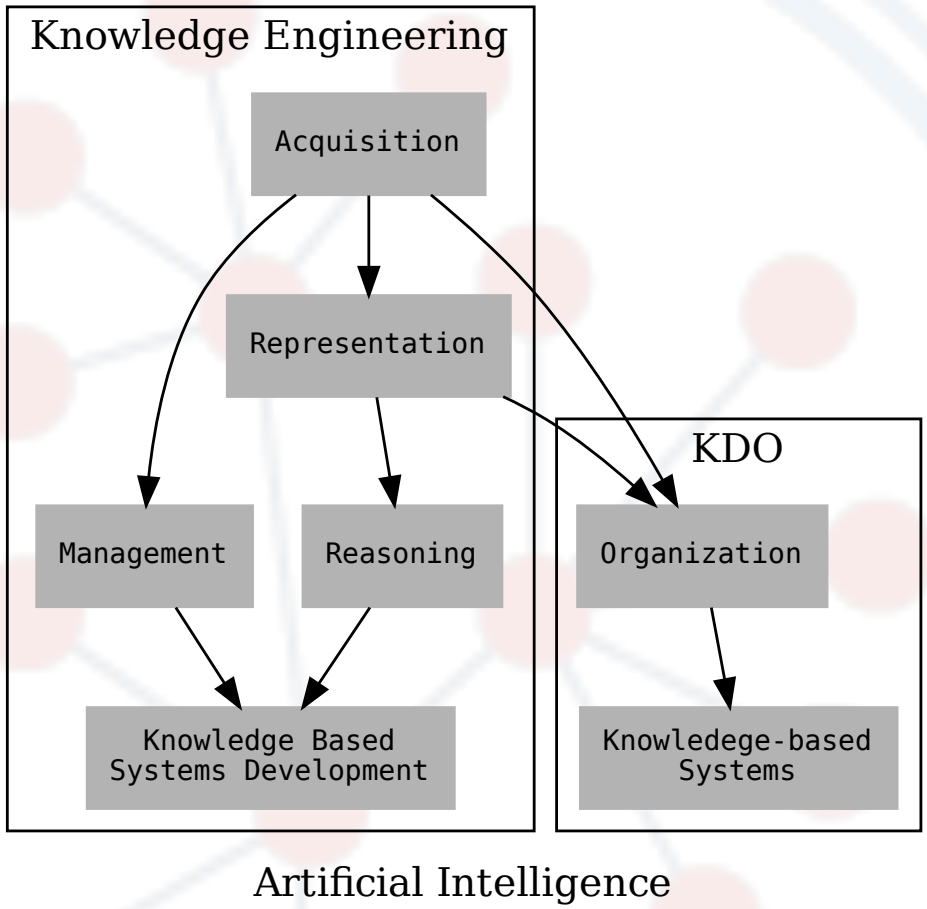
Major technological Changes



Source: World Economic Forum, The Boston Consulting Group

[4] WorldEconomicForum2016a.

Knowledge Engineering and Knowledge Domain Organization[5]



[5] Shiffrin2004; Boyack2004.

KDO and Literature Mapping[6]

Unit of Analysis	Fields and Paradigms	Communities and Networks	Research Performance or Competitive advantage	Commonly used algorithms
Authors	Domain Experts	Social and intellectual structure, dynamics	Network characteristics as indicators	Social network packages, multidimensional scaling, factor analysis, pathfinder networks
Documents	Field structure, dynamics, paradigm development	Influence and impact	Field mapping with indicators	Cocitation, co-term, vector space, LSA, PCA, various clustering methods
Journals	Science structure, dynamics, classification diffusion between fields	Trusted sources		Cocitation, intercitation
Words	Concepts and terms	Cognitive structure, dynamics		vector space, LSA, LDA
Indicator and metrics	Performance	Integrated performance	Comparisons of fields, institution, countries, etc., input-output	Counts, correlations

[6] Boyack2004.

Meta-Research[7]

Objective

- Research about research.
  - Investigate the methods, biases, and limitations of scientific research itself.
  - Quality and reproducibility of published research, effectiveness of research practices and tools, incentives and motivations that influence scientific behavior.
  - Identify problems and weaknesses in the scientific process. Improve research methods, increase the reliability of scientific findings, and optimize the use of limited resources.

Operation

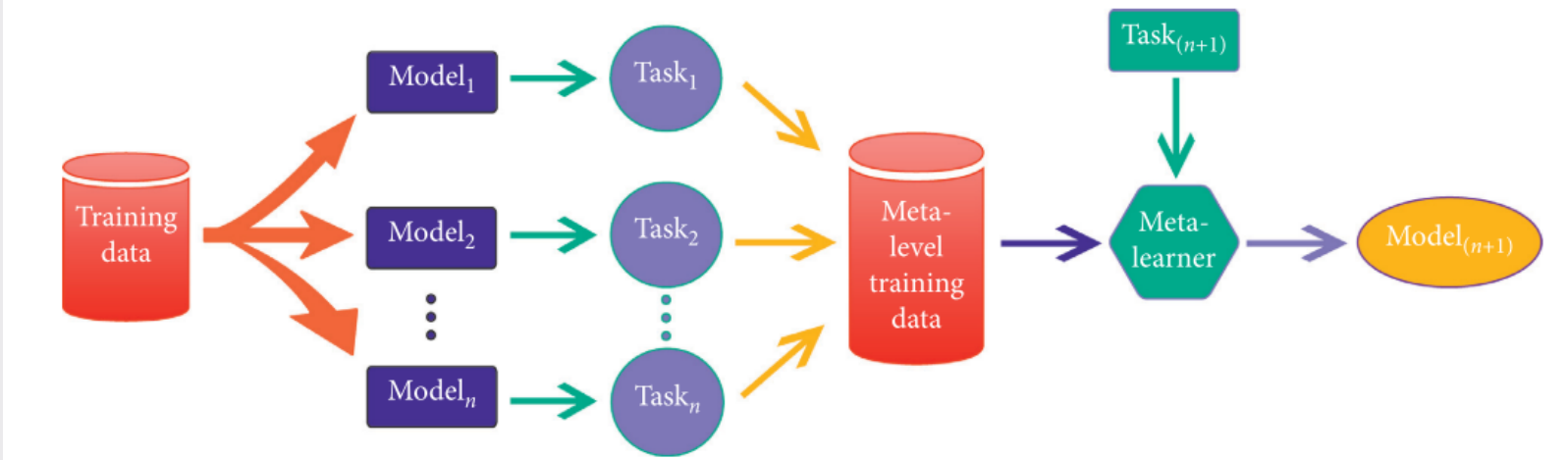
[7] Ioannidis2018.

Meta-Learning[8]

Learning to learn

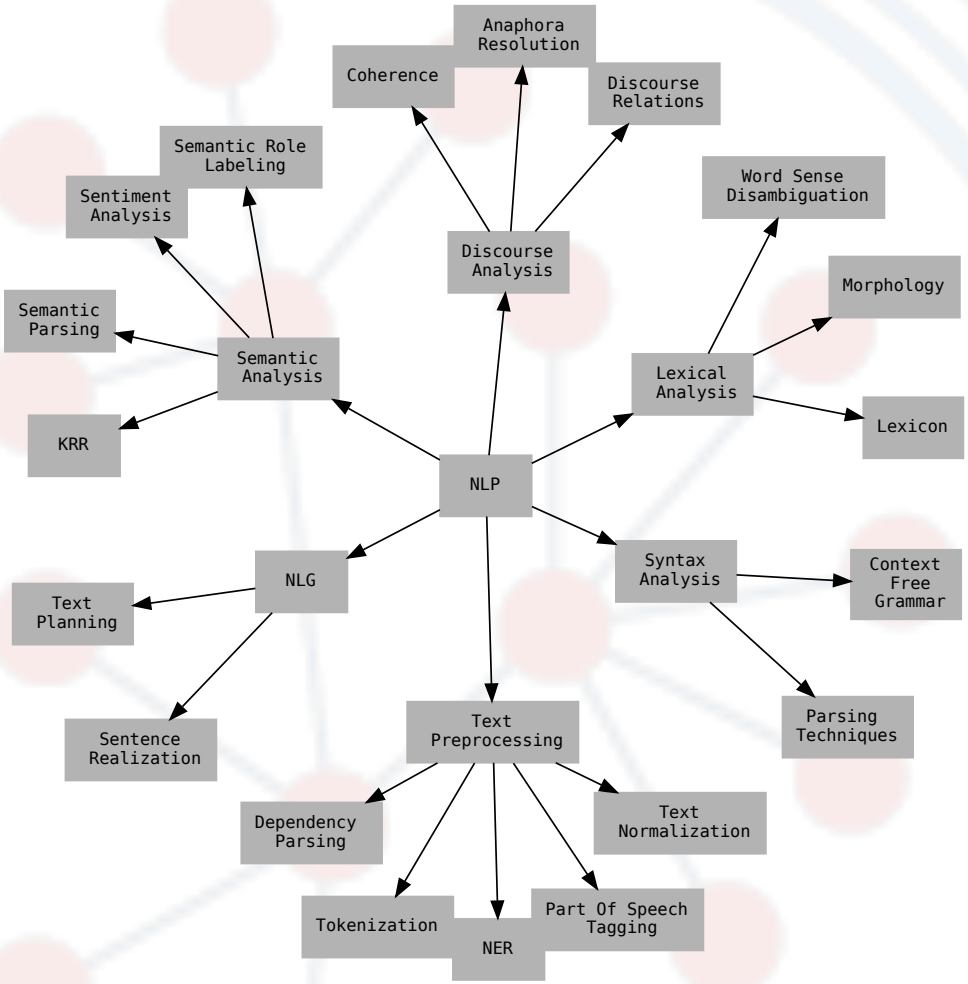
- Deep Meta Learning and Broad Learning Systems
  - To enhance the performance and robustness of learning systems.
  - Applied to various areas of AI

DeepML



[8] Ma2021; Chen2018Broad.

Natural Language Processing[9]
Leveraging Methods



[9] clark2013handbook.

Specifically[10]
At the AEC-AI 4.0 intersection

For the AEC-AI-4.0 Domain

- Can we assess the use of `Optimization Algorithms (OA)` in the `AEC-AI 4.0` Industry using a multilevel approach based on heterogeneous computational methods?.
- Defining the `KDO` structure relative to the use of algorithms in the `AEC-AI 4.0`'s life-cycle, in particular when relates to `OA`.
- For the AI/ML algorithms, it would be possible to evaluate:
  - How they are been used?
  - When they are been used?
  - Which requirements and constraints does different algorithm impose in the AEC' life-cycle?

[10] Darko2020; Maureira2021; Li_2019.

In general
For developing scientific domains

For a General Domain Knowledge

- It is possible to implement a general disruptive methodology to *tektology* (see **Bodganov1913**), by incorporating scientiometrics and artificial intelligence, and ciberphysical components to defining KDO structures.
- Such as that for some specific *domain of knowledge*, in a particular research field, general question can be addressed:
  - The main concepts and topics?
  - How they are been developed in time?
  - Where the main efforts are been allocated?
  - etc.

The *Working Hypothesis*[11]

Use of NLP:

- A *smart and significant* KDO structure of OA usage in the AEC-AI 4.0 Industry can be formed and implemented by using NLP models against literature research corpuses.

In particular:

- A KDO structure of OA in the AEC-AI 4.0 Industry at different levels can be addressed by using NLP techniques and LLM against literature research corpuses.

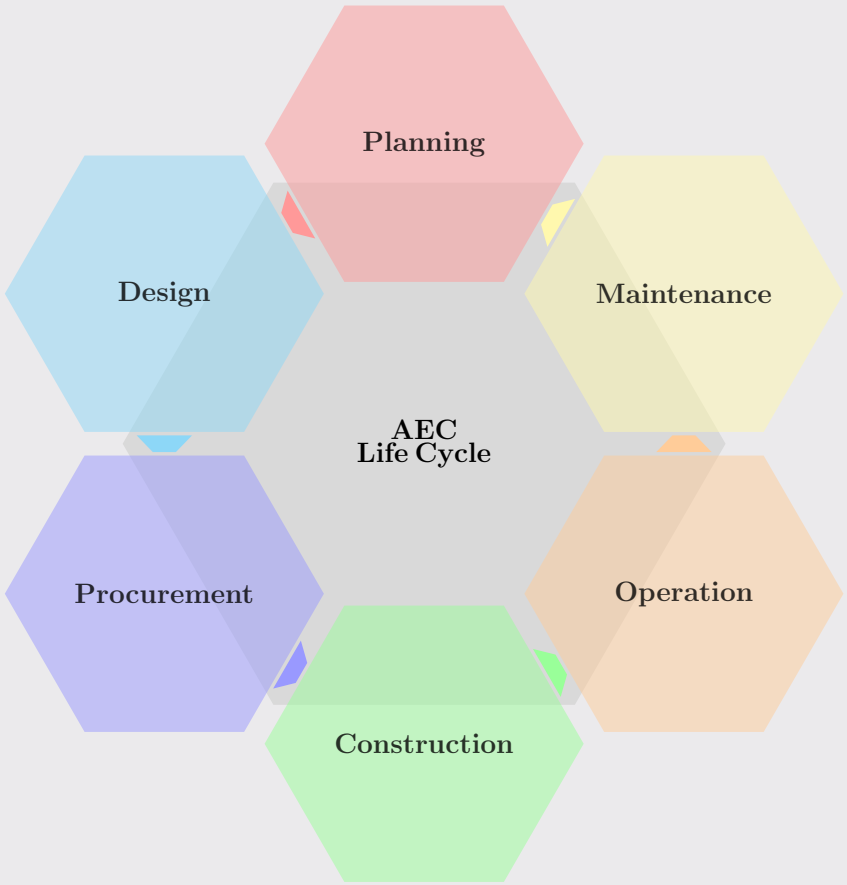
[11] Maureira2021; Maureira2022a; Maureira2022b.

KDO structures in the AEC-AI-4.0 Industry

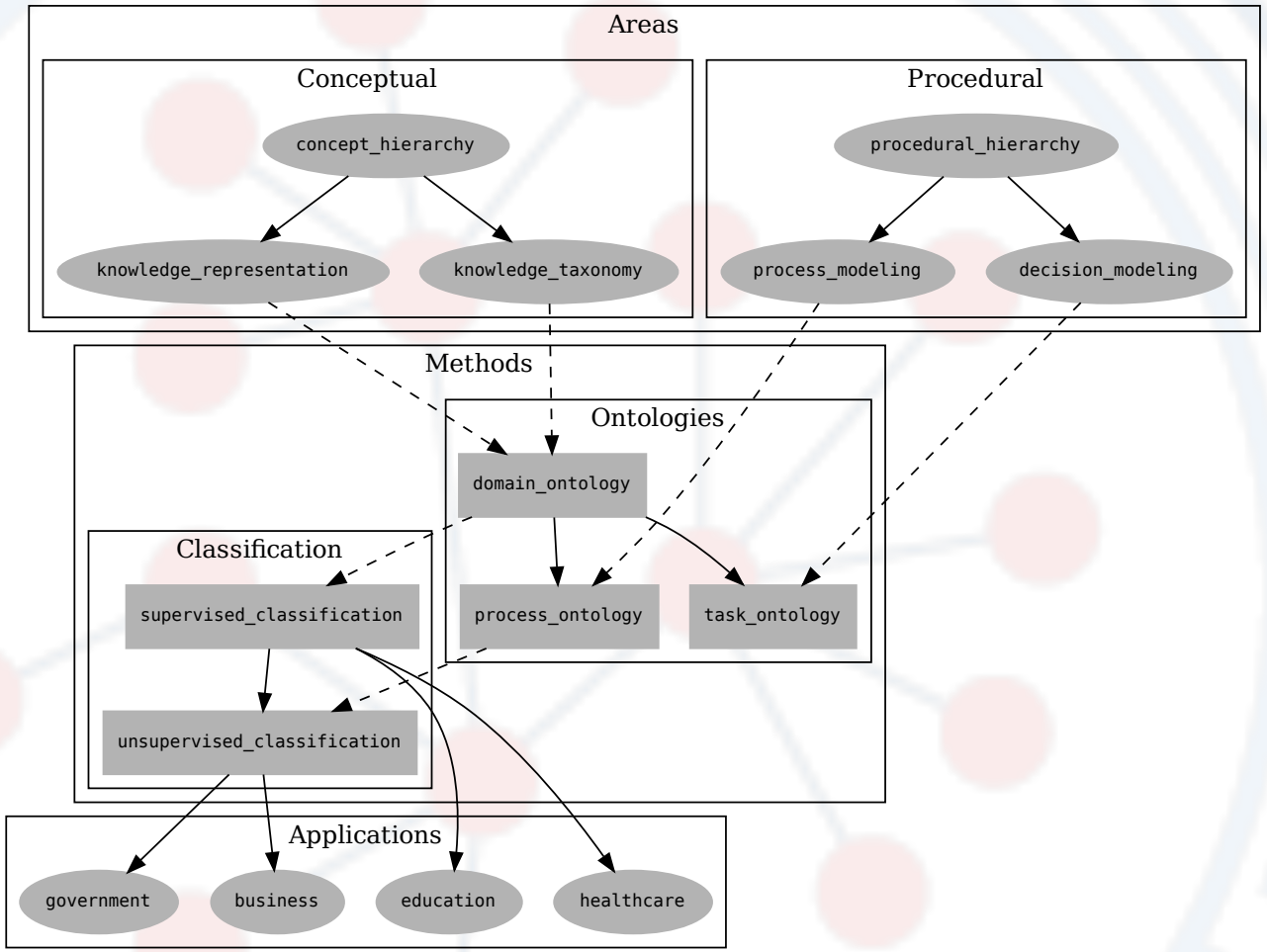
Integrated Operating System Framework

- Develop a multi-level methodology for Knowledge Domain Organization applied to scientific literature research corpuses in AEC-AI 4.0 Industry.
  - Allowing to determine, KDO structures such as: how, when and why OA methods are been used in the AEC-AI 4.0 life-cycle.
- Advance an adaptive integrated framework for analyzing life-cycle's problems including cyber-physical operations to forge an Integrated Operational System Framework (IOSF).
- The fields of AEC-AI 4.0, Knowledge Engineering and Meta-methods are considered the most relevant fields for an integrative approach.

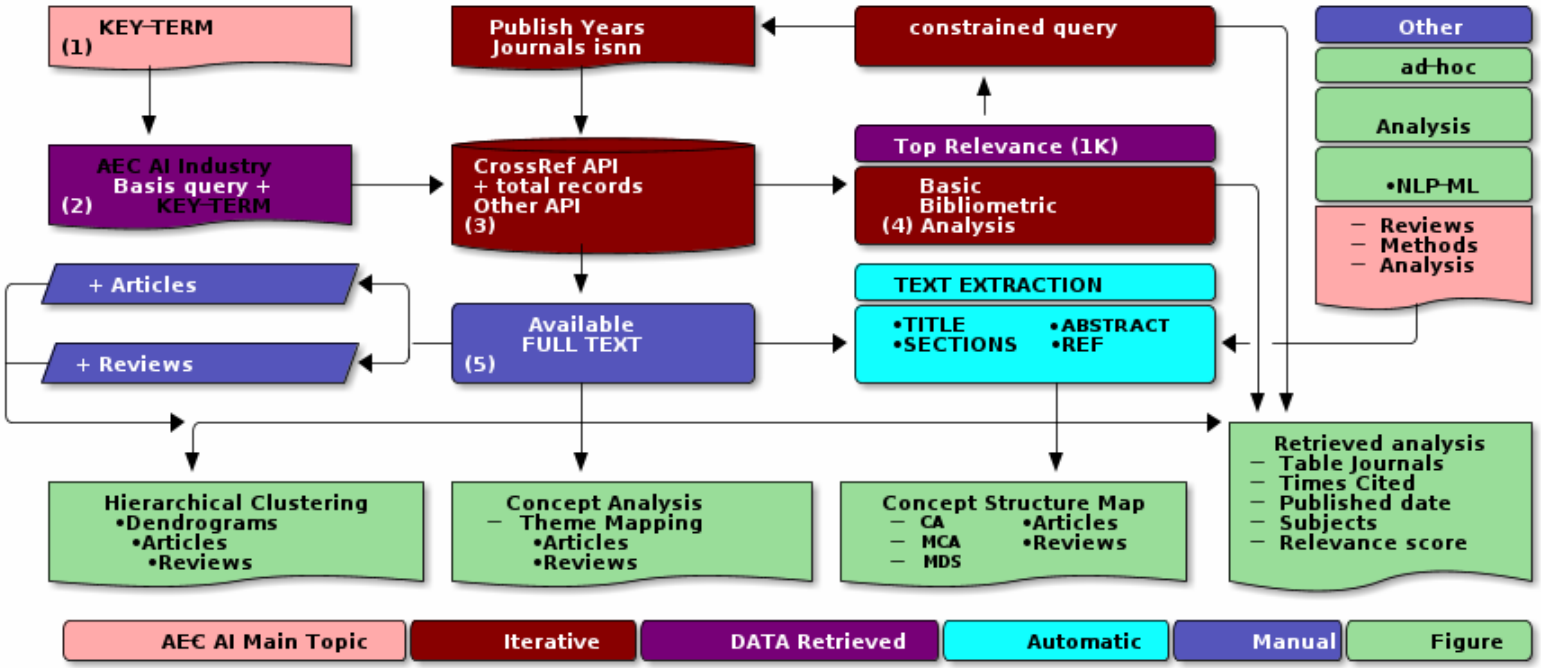
Lifecycle Optimization



Knowledge Engineering
Definitions, Representations and Visualizations



IOSF v0[12]
Further Developing



[12] Maureira2021.

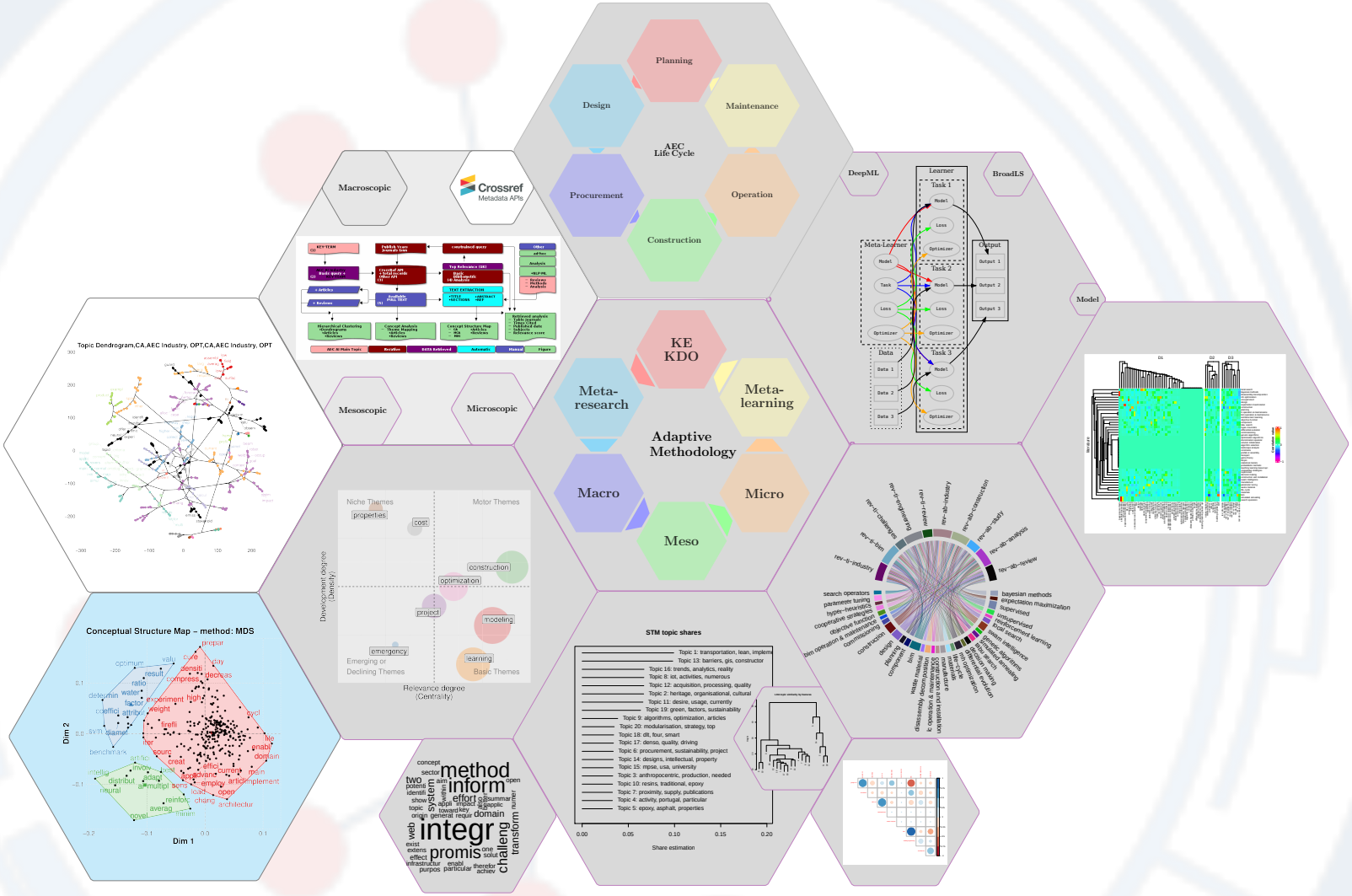
Adaptive Methodology Operation
The Operational Core

Iterative functioning of the adaptive methodology for the IOSF

- At the center, the Adaptive Methodology, reflex on the iterative processing of the system.
  - The Knowledge Engineering (KE) principles and methodologies will be used along with other principles and methodologies from Knowledge Domain Organization (KDO) to define relevant structures, processes and visualizations of the selected domain.
  - The processes related to defining the multilevel content refinement in the form of:
    - Macroscopical (Macro), Mesoscopical (Meso) and Microscopical (Micro) level definition for the target domain.
  - In the operation of the systems in a circular or cyclical transfer and interaction:
    - will use Meta-Methods for formation, representation, and visualization

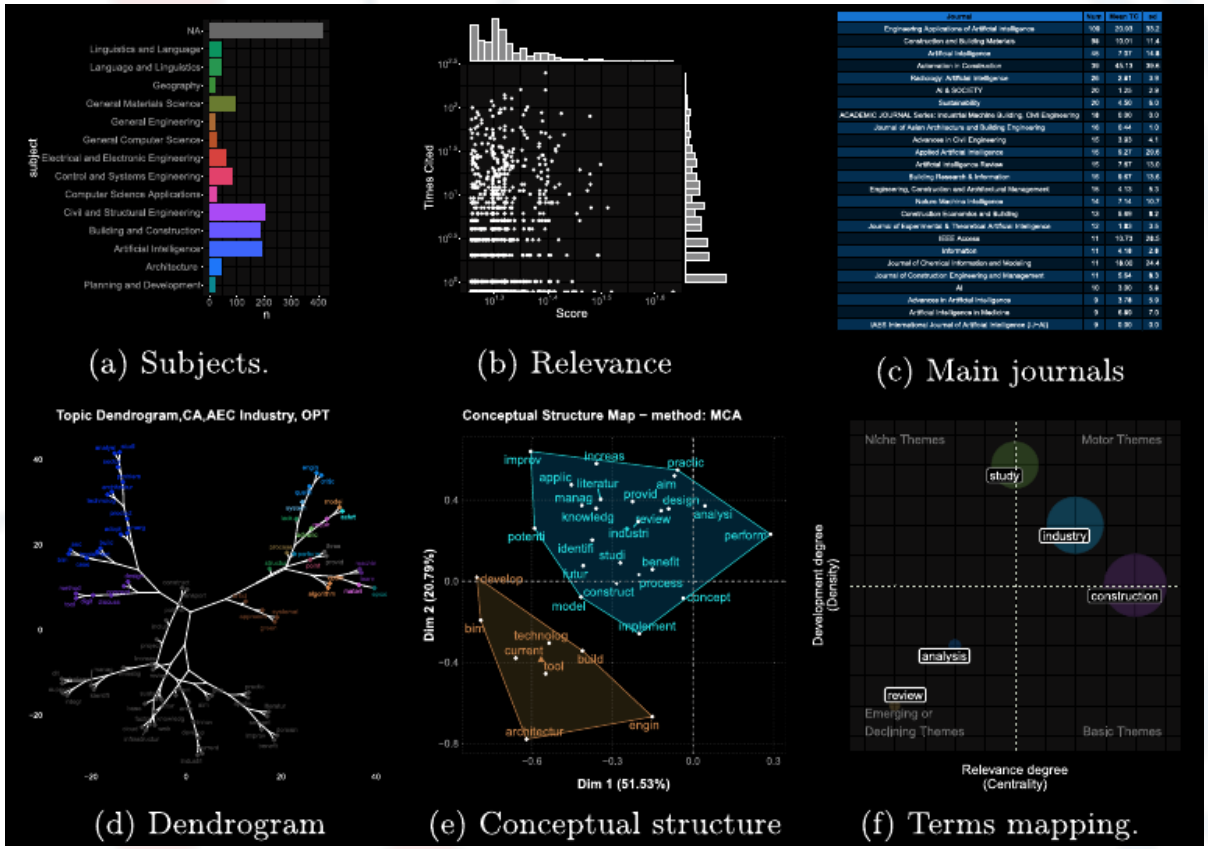
Adaptive Methodology Operation Diagram
Multi-level Adaptive Integration

Integrated Operating System Framework, IOSF: Schematic of components



Macroscopic Level[13]

- The analysis of the `Optimization Algorithms` key-term is equivalently coincident with the analysis provided by Scientometric analysis



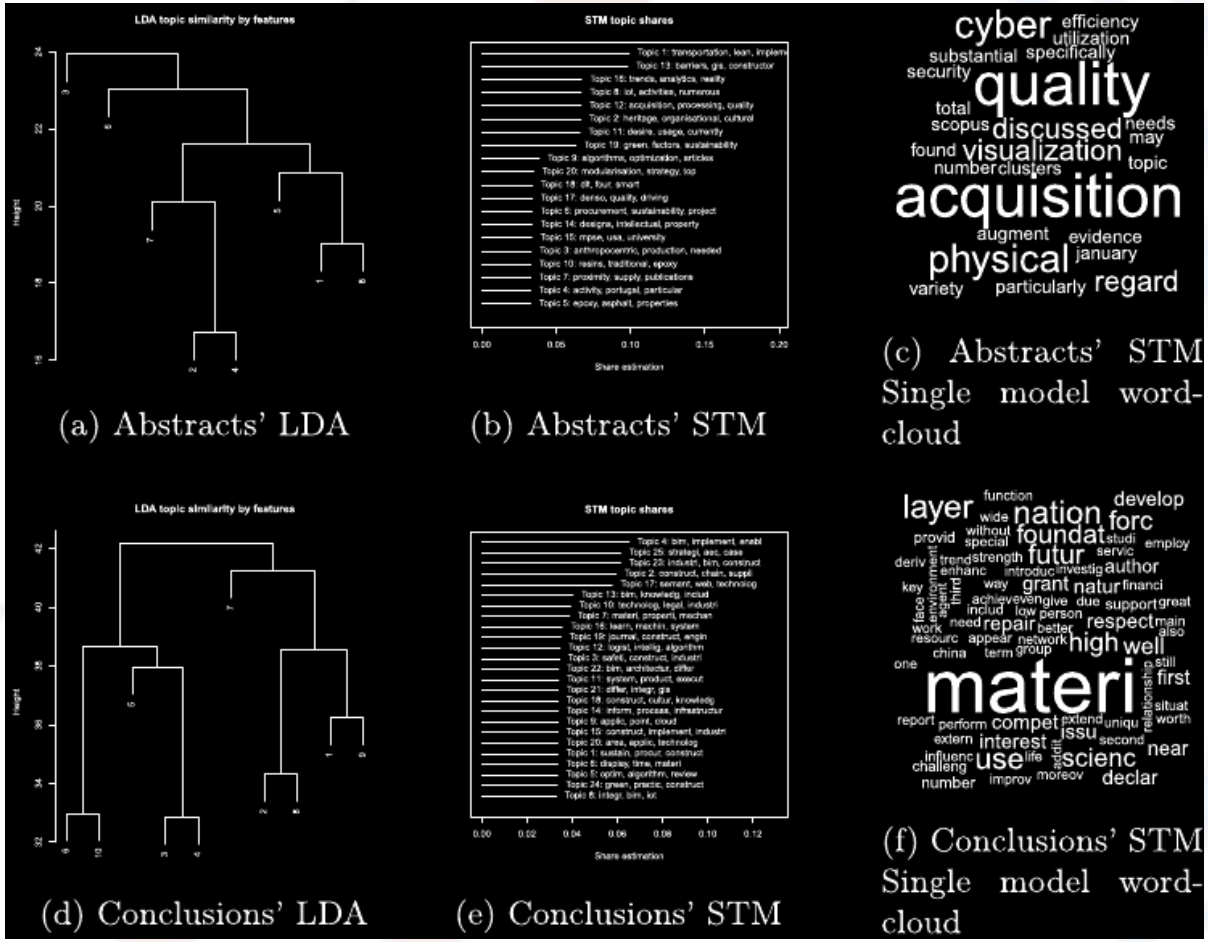
(a) Subjects. (b) Relevance (c) Main journals

(d) Dendrogram (e) Conceptual structure (f) Terms mapping.

[13] Maureira2021.

Mesoscopic Level

- Basic topic modelling with Latent Spaces



(a) Abstracts' LDA

(b) Abstracts' STM

(c) Abstracts' STM Single model word-cloud

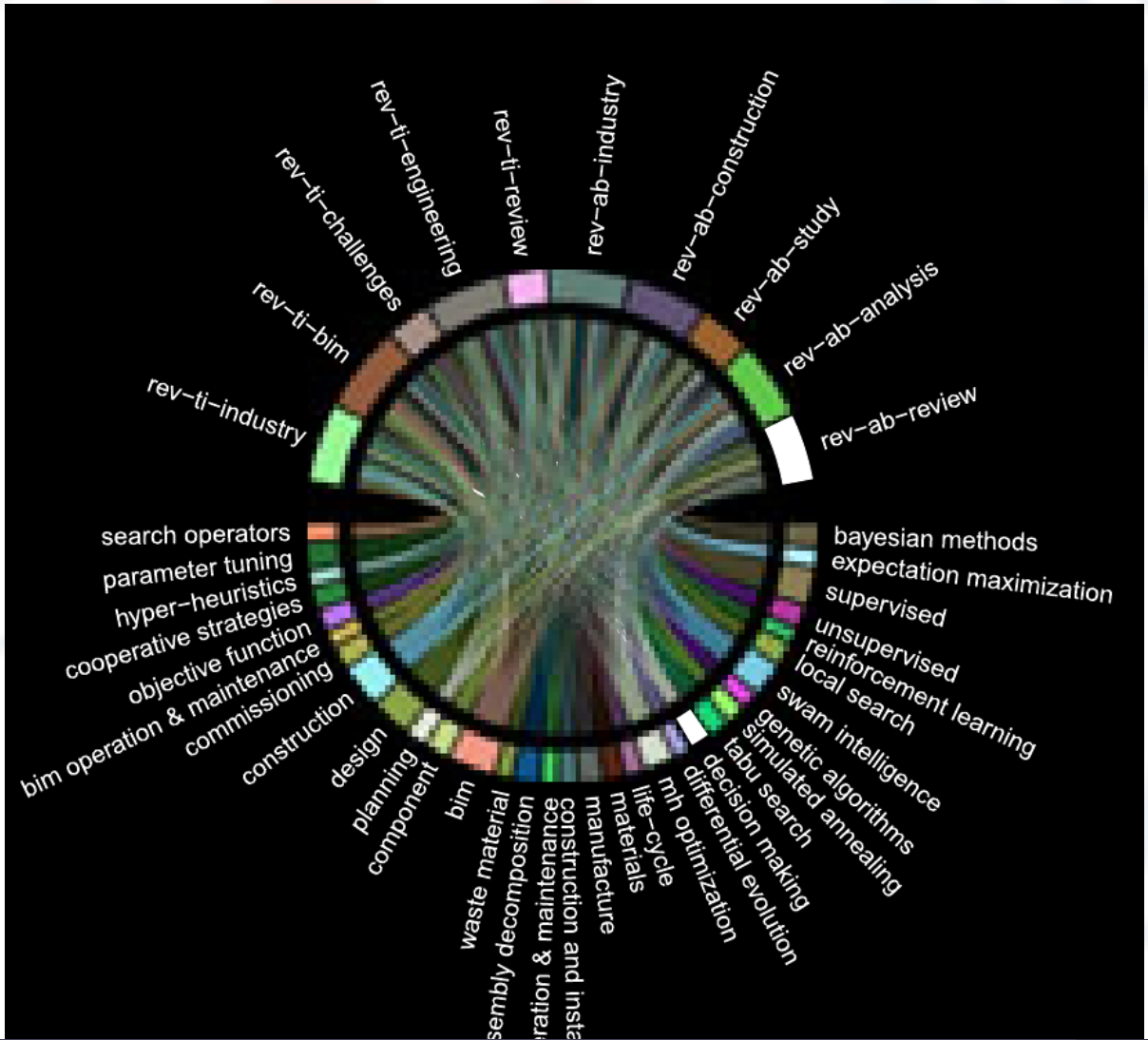
(d) Conclusions' LDA

(e) Conclusions' STM

(f) Conclusions' STM Single model word-cloud

Microscopic Level

- Ontologies



In Summary: the Research Results

Need

- ☐ It is already acknowledge
- ☐ Can be generalized

So Far

- ☐ Partially published
- ☐ Got some interest

Pending

- Leverage LLM
- Meta-learning
- Federated

Future

- Generalizable & Collaborate
- Working Framework
- Integrative

End

... Thanks you for your attention ...!!

References I