An ontology of knowledge components in the domain of Artificial Intelligence

Ciprian NEGURĂ

Doctoral School of Entrepreneurship, Engineering and Business Management (AIMA),
National University of Science and Technology POLITEHNICA Bucharest, Romania

ciprian.negura@gmail.com

Abstract: *In today's AI-driven world, business professionals need to understand the impact of Artificial Intelligence in both their industry and their professional activity and specific domain. But what factual, conceptual, procedural and meta-cognitive knowledge components do managers need to acquire such as to be more effective in their job? Not only what exactly do they need to understand but what tools can they use out of this very large domain of knowledge? In this paperwork we present an implementation of an ontology of knowledge components in the domain of Artificial Intelligence by using Neo4j knowledge graphs and how this can be used in the process of AI managerial competency development.*

Keywords: Ontology, Knowledge Graph, AI Competency Framework.

1. Introduction

This paper is part of a wider research in the domain of developing AI-enabled training tools for business professionals, more specifically a journey of developing an adaptive Intelligent Tutoring System to be used as a tool for training business management professionals in the domain of Artificial Intelligence (Negura & Ionescu, 2024).

In this paper we are describing our approach to modelling the Artificial Intelligence knowledge domain, namely an ontology of knowledge components in the domain of AI that will serve as one of the core components of the Intelligent Turoring System. The ITS's main function is to understand each learner's knowledge state and provide the most appropriate support in facilitating the development of AI competencies in line with his/her learning objectives.

Since the ontology is developed with this end goal in mind of serving as a knowledge base for the implementation of an adaptive learning algorithm targeted at business management professionals, concepts included in the ontology and their relationships are selected to be relevant given the needs and requirements of this specific target group. Furthermore, we also introduce in our resulting knowledge

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graph a Competency Framework that groups the knowledge components in specific competencies fit for each managerial role and seniority level.

According to the European Commission's Joint Research Centre (JRC) JRC121897 Technical Report on labour, education and technology competence is defined as "*a general ability to do well in a particular task domain*" (Rodrigues, Fernández-Macías & Sostero, 2021). This level of task domain competence is attained by learning and developing a mix of knowledge, skills, and attitudes specifically relevant to each business role (Rodrigues, Fernández-Macías & Sostero, 2021/02).

2. Taxonomies and ontologies in the domain of AI today

Many taxonomies and ontologies are built and used today especially with the rise of semantic networks and knowledge-based intelligent services. The World Wide Web Consortium (W3C) defined a common data model for interoperability between knowledge management systems called Simple Knowledge Organization System (SKOS) (Consortium, SKOS Reference, 2025).

2.1 Definition of taxonomy

Taxonomy is defined as "*the science of classification*" (Britannica, 2025) and is historically linked to the classification of biological entities. The term is derived from the Greek *taxis* ("arrangement") and *nomos* ("law") thus meaning the law of arrangement (based on specific criteria, but mainly in a hierarchy of classes from the most generic to the more specific categories/groups.

The most famous taxonomy in the filed of learning is Bloom's „taxonomy of educational objectives" (Bloom, 1982) originally published in 1956, and revised in 2000 (Anderson, Krathwohl & Bloom, 2000).

In business, a taxonomy is „a hierarchical framework used to categorize, classify, and group similar concepts, terms, and entities into categories and subcategories" (Times, 2025) (E.g., specialization (is-a) taxonomies, composition (part-whole) taxonomies).

2.2 Definition of ontology

Ontology is defined as "the philosophical study of being in general, or of what applies neutrally to everything that is real" (Britannica, Ontology, 2025). In knowledge management an ontology "encompasses a representation, formal naming, and definitions of the categories, properties, and relations between the concepts, data, or entities that pertain to one, many, or all domains of discourse" (Ontology (informaiton science), 2025).

Domain ontologies are constructed by identifying classes of objects/concepts and relationships among them (e.g. triplets of Subject – Verb – Objects). They are written in standardized formats using languages like the Web Ontology Language (OWL) (Consortium, 2025) and respecting standard data models like the Resource Description Framework (RDF) as per the specifications of World Wide Web Consortium (W3C).

2.3 Known AI ontologies

Some of the relevant ontologies in the domain of Artificial Intelligence in use today are:

- pedagogical/learning ontologies: SMARTIES (Mizoguchi & Bourdeau, 2000), (Hayashi, Bourdeau & Mizoguchi, 2009),
- ontology of AI Innovation: InnoGraph AI (Alexiev, Bechev & Ositsyn, 2023) (Massri, 2023).

3. Methodology

In designing the current AI ontology, we started form Bloom's taxonomy of educational objectives (Bloom, 1982) and followed our end goal of developing a model of the AI domain of knowledge fit for the purpose of supporting the development of AI competencies by business management professionals.

As such, the principles we followed in the development of this ontology were:

1. relevance: include the fundamental knowledge components that any business professional should be aware of and use in their professional activity, regardless of their main field/domain of expertise.
2. accessibility: group knowledge in a manner that allows non-technical professionals to gradually understand the concepts and adopt AI services in their specific area of expertise.
3. granularity: define knowledge components at a granular level that allows flexible grouping and use in different learning strategies.
4. completeness: include a set of knowledge components that reasonably covers the domain of AI and its corresponding subdomains.

We started by decomposing the factual, conceptual, procedural and meta-cognitve knowledge (Bloom, 1982) in the domain of AI in atomic knowledge components (Dai, Hung, Tang, & Li, 2021). For doing this, we have first built a dictionary of knowledge classes – see Table 1 – and then assigned each one of the specific knowledge elements in the domain of AI to its corresponding knowledge class.

Table 1. A dictionary of knowledge components classes in the domanin of AI

Knowledge Category	Class	Definition
MetaCognitive	Concept	understand the prerequisites, what one needs to know, and set-up the right expectations (e.g. expected learning progress rate)
MetaCognitive	Technique	how to approach learning
Factual	Fact	A piece of information that can be proven to be true or false based on evidence.
Factual	Event	An occurrence or happening, especially one of significance.
Factual	Person	An individual human being.
Factual	Publication	A work that has been published, such as a book, journal, or article.
Factual	Organization	A group of people structured and managed to meet a collective goal.
Factual	Product	An item or service that is created and sold in the marketplace.
Factual	Intelligent System	A system that uses AI to perform tasks that would typically require human intelligence.
Conceptual	Term	A "term" is a word or a group of words that has a specific meaning within a particular context or field of study.
Conceptual	Concept	A "concept" is an abstract idea or a mental representation that encapsulates a general notion or category. Concepts serve as the building blocks for thoughts, allowing us to categorize, interpret, and communicate about various phenomena, objects, or relationships.
Conceptual	Classification	The process of grouping items based on shared qualities or characteristics.
Conceptual	Infrastructure	The basic physical and organizational structures needed for the operation of a society or enterprise.
Conceptual	Architecture	The art and science of designing and constructing buildings; also refers to the structure of any system.
Conceptual	Category	A group or class of items sharing common characteristics.
Conceptual	Methodology	A system of methods and principles used in a particular discipline.
Conceptual	Framework	A basic structure underlying a system, concept, or text.
Conceptual	Model (AI)	A representation of a system or process that uses AI to simulate or predict outcomes.
Conceptual	Rule	A prescribed guide for conduct or action; an authoritative regulation.
Conceptual	Principle	A fundamental truth or proposition that serves as

		the foundation for a system of belief or behavior.
Conceptual	Regulation	A rule or directive made and maintained by an authority.
Conceptual	Technology	The application of scientific knowledge for practical purposes, especially in industry.
Conceptual	Theory	A supposition or a system of ideas intended to explain something.
Conceptual	Domain	An area of knowledge or activity.
Procedural	Language	A formal language comprising a set of instructions used in computer programming to implement algorithms and manipulate data structures, that produce various kinds of output.
Procedural	Library	A collection of functions used in computer programming (language-specific).
Procedural	Technique	A way of carrying out a particular task, especially the execution of an artistic work or a scientific procedure.
Procedural	Method	A procedure, technique, or way of doing something, especially according to a plan.
Procedural	Process	A series of actions or steps taken to achieve a particular end.
Procedural	Procedure	An established or official way of doing something.
Procedural	Algorithm	A process or set of rules to be followed in calculations or other problem-solving operations, especially by a computer.

The **Factual Knowledge** category contains classes like *Person*, *Organization*, *Event*, *Product*, and so on (see Table 1). These are both domain specific and factual in nature. The elements in these classes can generally be learnt / memorized being part of the theoretical dimension of the AI knowledge domain. Knowledge components in these classes need to be remembered and understood in order to be used in higher-order cognitive processes.

- Key contributors in the domain of artificial intelligence were assigned to the Person class. These are both scientists that proposed key concepts, theories, models, network architectures and so on, or public images of companies active in the domain (e.g. Sam Altman of OpenAI);
- Descriptions of AI-driven products like ChatGPT, Copilot, Gemini and so on were assigned to the *Product* class;
- AI-enabled notorious Intelligent Systems like AlphaGo, Deep Blue, Mycin and so on were assigned to the *Intelligent Systems* class;
- Companies, AI associations or other educational institutions active in the domain of AI were grouped under the *Organization* class.

Few other important factual knowledge classes refer to *Fact*s, *Trend*s and/or sources of information in the domain of AI like *Publication, Source, Book* or *Case Study*. These are all extremely useful in the process of learning, especially with our purpose in mind to develop adaptive learning algorithms that adapt the process to the specifics of each individual learner.

The **Conceptual Knowledge** category includes classes like *Concept*, *Classification*, *Theory*, *Methodology*, *Framework*, *Model*, *Architecture*, *Infrastructure*, and so on (see Table 1). These are also specific but more abstract and conventional (agreed within the community of practice). The elements in these classes also require memorization and proper understanding and involve higher-order cognitive processes.

- Definitions of terms ("What is…?") were grouped under the *Term* and/or *Concept* classes part of the Conceptual Knowledge category,
- Other key concepts like classifications, sub-domains of the artificial intelligence knowledge domain, main principles, theories, methodologies, network architectures, regulatory acts (e.g. EU AI Act) and so on, were assigned to the corresponding specific classes in the Conceptual Knowledge category.

The **Procedural Knowledge** category includes classes like *Algorithm*, *Procedure*, *Method*, *Technique* and so on (see Table 1) that describe practical/procedural knowledge to be applied in higher-order cognitive processes like use/apply, analyze, evaluate or create new knowledge. Developing new skills is based on the proper use of such procedural knowledge in the context of the tasks and challenges specific to each managerial role.

- The main procedural knowledge components in the domain of Artificial Intelligence were assigned to classes like *Algorithms* (e.g. regression, classification, k-means, support vector machines, etc) *Procedure* and *Technique*;
- Definitions and links to programming languages like Python or R are assigned to the class called *Language*;
- Corresponding programming language libraries are assigned to the *Library* class. This differentiation of librabies from programming language (the *Language* class) allows for higher flexibility in using the ontology for upskilling / learning recommendations.

The **Metacognitive Knowledge** category is extremely important for the process of competence development. It covers several aspects of learning and training like: *Concepts* (e.g. "*know what one needs to know in the domain of AI*") or learning *Techniques (e.g. "how to approach learning in the domain of AI")*.

4. Results

The resulting ontology and thus the entire relevant knowledge in the AI domain were coded in a knowledge graph (Singhal, 2012) using the Neo4J tool (neo4j.com) with the consideration of relevant classes and relationships defined in the earlier stages.

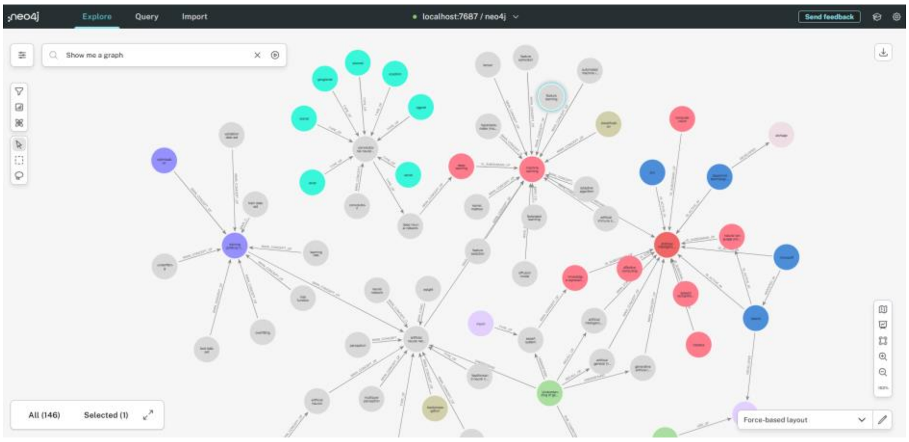

Figure 1. AI knowledge domain

Each node in Figure 1 above represents a specific knowledge component in the AI knowledge domain, an object of a specific type (class). The color of the node represents the class (each class is represented by a different color in the graph). Relationships between nodes are displayed as connecting links (edges) with the name on the link representing the nature of the relationship (e.g. TYPE_OF, or MAIN_CONCEPT_OF).

The knowledge graph (KG) is a very flexible structure that can be easily extended with new classes and relationships. Moreover, additional relationships can be added between the nodes in the graph (existing and/or new) and both nodes and relationships can be assigned properties to store class-specific attributes.

The Neo4J knowledge graph allows us both to reason and operate with knowledge in the AI knowledge domain by using the Cypher Query Language (https://neo4j.com/product/cypher-graph-query-language/). As such, the graph can be used as the knowledge domain model in an Intelligent Tutoring System (ITS).

5. Discussions

Once we developed this flexible model of knowledge in the domain of Artificial Intelligence, we extended the knowledge graph with a couple of new classes so that we can use it in the process of managerial upskilling.

In a separate phase of our research, we developed an AI-competency framework fit for the purpose of upskilling management professionals. The framework contains both AI Fundamental competencies (e.g. understanding of general AI concepts and the AI ecosystem, organizing AI-based business processes, principles and ethics in AI, Ai regulation and basic use of AI tools) as well as higher order AI competencies specific to the planning, organizing, leading and controlling functions at various management levels.

A *Competency* class was added to the KG to accommodate the definition of specific managerial competencies required in business – see green nodes in Figure 2. This allows us to overlay an entire competence framework on top of the AI domain model and link each competency to its corresponding knowledge components in the knowledge domain. Since a competency is defined as the collection of knowledge, skills, attitudes and other personal characteristics that allow a manager to be performant in his/her role (Spencer & Spencer, 1993) each competency is linked to both the factual and conceptual knowledge components but also to procedural knowledge that allows a manager to use the relevant procedures, methods, algorithms and techniques in solving the tasks and challenges specific to the role.

A *Lerner* class was also defined and added to the graph to store information about the learners including several profiling properties: age, gender, socio-professional attributes (role, employer/company) or psychological profiling attributes relevant to the learning process. This class allows us to define each learner as a node in a corresponding knowledge graph and trace his/her development in time but this is outside the scope of the current paper.

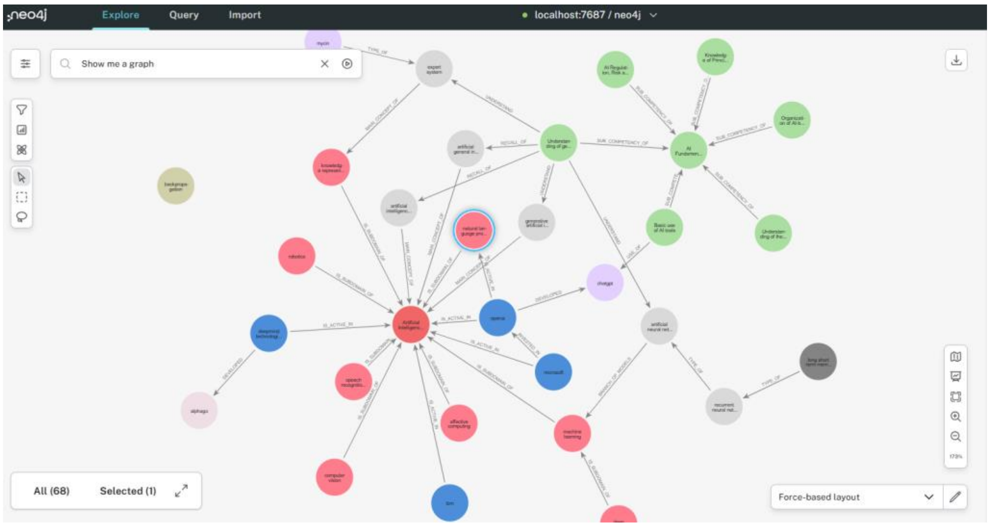

Figure 2. AI knowledge domain

6. Conclusions

Knowledge graph (KG) technology allowed us to develop a model of the AI domain of knowledge that can be used in several applications. While we constructed the graph manually, today's AI models, especially the LLMs, and techniques (e.g. Name Entity Recognition) allow automation of the process of expanding the KG with additional classes and/or knowledge components.

Moreover, frameworks like the LangChain allow easy integration of the KG both in applications developed in several programming languages (e.g. Python, Java, etc.) as well as linking the KG to LLMs in a Retrieval Augmented Generation (RAG) configuration.

A topic of further exploration is the specific algorithms that should be used in tracking the progress of each learner throughout the process of developing the target competencies (a.k.a. "knowledge tracing").

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