Evolution of LMS Design and Implementation in the Age of AI and Large Language Models

Andrea Molinari [1,2], Simone Sandri [3]

[1]Dept. of Industrial Engineering University of Trento, Trento, Italy
[2]Lappeenranta University of Technology, Lappeenranta, Finland
[3]Okkam s.r.l., Trento, Italy

Abstract
The integration of generative AI and large language models (LLMs) into Learning Management Systems (LMSs) offers significant potential but remains underutilized. Current implementations typically involve the LMS requesting services from an AI engine, such as responses, suggestions, and content summaries, reflecting a superficial interaction between two distinct systems. This limited integration arises from the architecture of most major LMS platforms (e.g., Moodle, Docebo, Sakai), which were designed in the early 2000s. These systems are structured around relational databases and multi-layered logic, which separates business logic from the user interface. While they offer extensive multimedia resources for education, their content is generally organized into folders based on modules or lessons, limiting their adaptability to modern AI functionalities. Additionally, while some platforms support text-based interactions (forums, FAQs, blogs), their overall design remains outdated. This paper proposes a new software architecture for LMSs, designed to natively support AI functionalities. It advocates for a shift from relational to graph-based models for content storage, allowing the creation of a knowledge graph that integrates ontological frameworks. This transformation would enable more advanced AI-driven functionalities, such as content recommendations, semantic searches, and personalized learning experiences. We also address the challenges inherent in such a transformation, including a) the need for a complete redesign of the platform's persistence and business logic layers; b) the complexity of integrating multi-domain ontologies within educational institutions; and c) the technological hurdles in training large, adaptive language models that can evolve in real-time, especially during periods of high content generation.

Keywords
Learning Management Systems, Knowledge Graphs, Named-entity recognition

1. Introduction

Since the early years of their appearance on the market, learning management systems (LMSs) have reached a high level of maturity[17], providing professional solutions to almost any educational need. Nowadays, the availability of many different cloud-based collaboration tools puts the specific characteristics of LMS services and pedagogical approaches to learning in the shade. The dramatic pandemic that started in 2020 highlighted the importance of technology-enhanced learning (TEL) as a crucial part of the information system of any institution. The advent of generative AI and LLM[11][12][13] poses a plethora of improvement areas for Learning Management Systems (LMSs), even though their integration in LMS systems is still very limited compared to their potential. Beyond the advertising brochures, this integration is mostly devoted to the interaction between two different systems, where the LMS requests services from an AI engine, awaiting responses, suggestions, aggregations, summaries, and everything else we know that current generative AI services can provide on provided content.

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* Corresponding author.
† These authors contributed equally.
andrea.molinari@unitn.it (A. Molinari); sandri@okkam.it (S. Sandri)
0000-0002-9922-9479 (A. Molinari)

This lightweight integration stems from a fundamental software engineering problem: major Learning Management Systems (LMSs) such as Moodle, Docebo, and Sakai are large-scale software applications conceived in the early 2000s. Consequently, they exhibit structural characteristics typical of that era, such as web applications primarily based on relational back-ends and multilayer logic that separates parts of the logic from the user interface and user experience. One distinctive aspect of these platforms is the wealth of multimedia content tied to training processes. Although this abundance offers significant potential for modern artificial intelligence tools, the content is predominantly organized into folders corresponding to modules, courses, lessons, or other instructor-defined structures. The textual content spans various educational applications and institutions, with more advanced systems incorporating textual interactions such as forums, FAQs, newsgroups, blogs, and other text-based forms.

Drawing upon knowledge developed over the past 25 years in constructing software platforms for e-learning, this paper analyzes the internal structure of an LMS and proposes a new software architecture better suited to natively accommodate the functionalities provided by AI in the education sector. This approach necessitates a comprehensive revision of the mechanisms for content creation and storage in an LMS, enabling native operation to create a knowledge graph upon which various functionalities can be built. Adopting a graph model instead of a relational model for content, along with the by-design integration of content with its ontological description, could lead to a disruptive new generation of LMSs [14][15], particularly in terms of functionalities and services provided to users.

In this paper, we will illustrate our vision of the issues and needs for a profound conceptual redesign and implementation of these platforms, aware of the challenges related to a) the complete redesign and implementation, at least of the platform's persistence layer and part of the business logic layer, b) the complexity of integrating an ontological description of multi-domain situations, typical of an educational institution, and c) the technological complexity in training large language models—probably not too large, but certainly with the need to evolve almost in real-time due to the constant addition of new content during more intensive educational periods.

2. AI and LMS integration: a literature overview

The integration of artificial intelligence (AI) into Learning Management Systems (LMS) has been a growing area of research, with many scholars examining its potential to enhance learning experiences through personalization and automation. In a foundational study, [1] explores the role of AI within LMS platforms, specifically focusing on how adaptive learning systems and data-driven personalization can tailor educational experiences to individual learners. This study underscores the significance of AI-driven adaptation in creating dynamic and responsive learning environments.

Similarly, in [2], the authors delve into how AI can be integrated into LMS to offer more customized learning paths. Their research highlights the potential for AI technologies to enhance learner engagement by offering tailored learning experiences based on student performance and preferences. By harnessing machine learning algorithms, LMS platforms can continuously assess learner needs and adjust the educational material accordingly, making the learning process more efficient and personalized.

A systematic review by [3] provides a broader perspective, covering various AI applications within LMS platforms. This review includes emerging technologies like GPT (Generative Pre-trained Transformers) and their integration into LMS for learning personalization. The study emphasizes the growing trend of utilizing language models to generate content, offer intelligent tutoring, and facilitate more meaningful student-teacher interactions.

In a comprehensive analysis, [4] expands on the incorporation of AI, including advanced language models, into educational platforms such as LMS. This research explores both the benefits and potential risks associated with AI in education, such as improving engagement and performance while cautioning against over-reliance on automated systems. The article presents a balanced view of how AI tools can transform traditional learning methods while maintaining a critical perspective on ethical and practical challenges.

[5] takes a closer look at natural language processing (NLP) models like GPT within LMS, focusing on their use for generating student feedback, creating educational content, and improving overall student engagement. This research demonstrates the practical applications of language models in facilitating learning through automated content generation and interactive dialogue, which can provide students with timely feedback and support.

Anticipating future developments, reference [6] discusses potential directions for AI-LMS integration, focusing on tools like GPT. The authors speculate on the evolution of collaborative learning environments with AI's increasing role in fostering student collaboration and providing personalized, real-time feedback. The study examines how AI might influence both individual learning trajectories and group dynamics within online education platforms.

Reference [7] investigates how adaptive AI systems, including GPT-based models, can transform LMSs to better meet student needs. The research highlights the potential of intelligent tutoring systems to deliver personalized content tailored to individual learning styles, requirements, and progress. By adapting in real-time to provide the most relevant and effective educational material, these systems significantly enhance student engagement and learning outcomes.

The implications of integrating AI tools into LMSs are further explored in reference [8], with a particular emphasis on higher education. This study considers the transformative potential of AI technologies for teaching and learning, underscoring AI's role in reshaping educational strategies and administrative tasks. The paper suggests that AI can enhance the teaching process and streamline assessment and feedback mechanisms, rendering the entire educational experience more efficient and effective.

[9] centers on the opportunities offered by generative AI, such as GPT models, in enhancing content creation and learning strategies within LMS platforms. This article highlights how these AI tools can be employed to generate high-quality educational materials, freeing instructors to focus on more interactive and student-centered teaching approaches. It also discusses how AI-generated content can be customized to meet the diverse needs of learners.

Finally, [10] discusses how GPT tools can support collaborative learning approaches within LMS platforms, promoting personalized feedback and improving communication between students and educators. The research emphasizes the value of AI in creating more efficient feedback loops and fostering a more interactive, student-centered learning environment. By enabling personalized feedback, GPT tools help bridge the gap between automated systems and human instruction, leading to improved learning outcomes.

AI and educational technologies are crossing their research paths in many sectors, involving different disciplines and different aspects of the educational process. For a comprehensive analysis of these aspects, a broader literature overview is presented in [17].

3. LMSs' architectural integration of AI features

The major Learning Management Systems (LMS) are large-scale software applications, conceived in the early 2000s, if not earlier. Therefore, they exhibit structural characteristics typical of those years: web applications predominantly based on a relational back-end and multi-layered, multi-tier logic (usually three layers: persistence layer, business logic, and presentation layer) that enable the separation of part of the application logic from the user interface and user experience.

The distinctive feature of these platforms is, of course, the vast array of services related to educational processes and multimedia content. This represents a significant potential for modern artificial intelligence tools. However, the content organization is primarily folder-based, likely linked to a module, course, lesson, or any other structure defined by the instructor. Inside these folders, content is found in various formats, though predominantly in PowerPoint, PDF, or similar formats for textual materials. Textual content on the platform is also stored within the relational database (or NoSQL in more advanced cases), particularly in applications related to user interaction such as forums, FAQs, newsgroups, blogs, and other primarily text-based formats.

Historically, there has always been a functional and architectural need to provide both instructors and participants in the learning processes with search tools to identify, aggregate, and display content. However, this need is not as central as it is in other fields, such as finance or banking, where search precision is crucial. Educational content, although organized by instructors, is usually easy for learners to retrieve.

What artificial intelligence, particularly generative AI, offers today represents a series of functionalities that are currently either non-existent or exist in an experimental form, and certainly not capable of providing the high-quality and timely results that modern tools like ChatGPT, Jenni, Claude, Llama, etc. (focusing here on GPT-based tools for textual documents) can deliver. This refers not only to document search and retrieval functions relevant to users' needs but especially to pure generative functions, where the AI system, properly trained on the knowledge contained within the LMS, generates new content, augmented by the necessary general and domain-specific knowledge. If we consider the realm of multimodal generative AI, the gap between what LMS platforms currently offer and what could potentially be offered through generative capabilities is even more significant.

To analyze this potential, we have a paradigmatic case at our disposal. "Online Communities" is one of the first comprehensive European LMS platforms (1998), at a time when tools like Blackboard™ and WebCT™ were prevalent. This platform was internally developed by our research group and later integrated into commercial products, while its use continued within various public and private institutions. Currently, the knowledge base linked to the platform consists of approximately 2.2TB of textual documents or contents, which presents a far simpler dataset for training a large language model compared to the general training performed by major market players today.

This research explores the possibility of integrating an LMS with generative AI services, providing collaboration, communication, accounting, authentication, recording, and document-sharing solutions [6], optimizing the user experience and the total cost of ownership of such integration. It focuses on developing an LMS towards it being a more "intelligent" platform, in the sense of satisfying the requests of AI-based services so common in the industry today, but specialized for educational context.

The research is in its early stages as it represents a profound and highly impactful shift for well-established and widely used platforms, which, however, exhibit structural elements that are not fully compatible with complete integration with the world of generative artificial intelligence. We are indeed convinced that, just as has occurred with many other IT systems, we will undoubtedly witness a race in this sector as well, with announcements of integration with various engines or the presence of AI services.

Given access to the entire source code, all structural knowledge, and the content of a medium-to-large platform, we believe that such integration will be much deeper and, therefore, cannot be limited to a few API calls exposed by major providers. The transformation we are envisioning and beginning to implement is a total and profound change, particularly within the knowledge base. This base, which currently relies on a relational model for structured parts and a file system for content, should transition towards a true structured knowledge base in the form of a knowledge graph, where the various nodes consist of entities recognized by the system, aiming to create more coherent links.

The primary research objective is to demonstrate how LMSs could be a building block for any information system, as they can provide a set of essential services for corporate IT. Above all, they can be used as educational tools and generalized tools for collaboration. We want to stress how e-learning can be considered a more comprehensive collaboration between teachers and learners. This consideration has been reinforced by recent research trends that have adopted new educational theories and practices. There is a much less unbalanced teacher and learner relationship versus a more peer-to-peer one. As examples, we can mention approaches related to co-learning, flipped classrooms, and all the approaches in which we must consider participants as peers and not simply as “students”. More appropriately, they are components of a knowledge-transfer process with educational and training, professional, and vocational purposes.

Artificial intelligence (AI) is transforming Learning Management Systems (LMS) by enhancing the effectiveness of learning, the personalization of educational experiences, and the efficiency of managing educational activities. AI within LMS platforms is revolutionizing the learning process by improving personalization, accessibility, and efficiency in managing content and courses. From adapting learning pathways to automated assessment, AI enables a more dynamic and targeted learning experience for both students and teachers, with positive impacts on the quality and effectiveness of learning.

Below, we outline the main ways AI can be or is being used—though often not natively—within LMS platforms, based on the information available at the time of writing. It is important to highlight that, when present, these AI functionalities are often mere extensions of current platforms rather than fully rethought or re-engineered for better utilization of AI capabilities. Instead, they typically query external engines via API calls. These API calls to external AI-based frameworks, or most recently to the API exposed by large language models (LLMs), results are processed and then presented to the end-user in the original GUI. However, in this case, a) the LMS’s document base needs to be partitioned and passed to the GPT model being used, or the whole knowledge base must be first processed for the training phase and then updated each time new content is added, and b) beyond performance, the LLM may have general knowledge of the world and (potentially) the educational domain in question, but it certainly does not have specific knowledge of the domain and content of the educational material of this particular institution.

The risk of "hallucinations" is therefore significantly higher, meaning that when conducting a specific search within the material of a course, from a particular professor and institution, the response could be generalized and based on training materials that are entirely different, potentially better (or worse), but not contextualized to the ongoing educational activity.

We might define these as "local hallucinations," referring not to the known issue produced by LLM (an answer entirely or partially disconnected from the reality and facts about the subject), but rather to a hallucination related to the difference between the local domain of the educational institution and the broader domain on which the LLM has been trained. In perspective, this leads to one of the known issues associated with the widespread use of generative AI models: the flattening of knowledge based on what the LLM has learned and how it has been conditioned by the documents provided for training.

This phenomenon can result in AI-generated responses that, while plausible, lack the necessary specificity and contextual accuracy for the particular educational materials or domain in question. Over time, the risk is that knowledge becomes overly standardized around the content that the LLM was trained on, potentially neglecting the richness and diversity of local educational contexts. This could dilute the uniqueness of course materials and reduce the specificity that teachers and students rely on for effective learning.

The structural change proposed in this paper represents a crucial and complex step essential for fully harnessing the capabilities of artificial intelligence. This transformation ensures greater consistency in representation, enhances service extensibility, and often improves performance outcomes. For example, consider the native representation of a document in PDF format versus its transformation into a graph through natural language processing (NLP) systems. In the graph, entities are interconnected and mapped to ontology concepts, illustrating the radical difference between two systems housing the same knowledge. In the second case, where information is structured as a knowledge graph, the system becomes inherently more efficient and effective for AI processing. This approach not only allows AI tools to handle data more coherently and intelligently but also increases service scalability and enables the integration of advanced functionalities such as entity recognition, relation mapping, and semantic reasoning. Ultimately, this shift results in a more robust and reliable AI-driven system capable of delivering highly relevant and contextually accurate results, particularly in educational contexts where precision and contextual understanding are paramount.

The areas for improvement and integration with AI services are numerous and highly intriguing, given the wide range of services that an LMS provides. Below, we offer a brief overview of the main areas of interest—aside from the aforementioned search features—followed by a presentation of the structural changes we have begun implementing within the platform under examination.

These improvements target key functionalities such as personalized learning pathways, enhanced content search capabilities, automated assessments, and adaptive learning environments. Additionally, the integration of AI-driven tools for feedback, student performance tracking, and resource recommendations could significantly enhance the overall user experience and efficiency of the platform. In the following sections, we will delve into these enhancements, exploring how they can be structurally integrated to maximize the potential of the LMS while ensuring scalability, coherence, and optimal performance in handling AI-driven tasks.

Many other features can be provided from scratch, or improved by the use of (generative) AI inside the LMS, provided that the architecture of the platform has been natively set up for this integration. From personalized learning to automated assessment and feedback, from the chatbot and virtual assistants to predictive analytics of learners' performances, and from microlearning to content aggregation and generation, the whole set of services traditionally provided by an LMS will benefit from this integration. Among the services offered by LMSs, content search is the most closely aligned with modern AI capabilities. Many users now prefer AI-driven tools like Perplexity AI, which provides faster, more accurate results than traditional search engines. AI-driven search functionalities can transform how users access educational materials, improving engagement and enhancing learning. In the redesign of our LMS, we identified several AI-driven improvements:

- Semantic Search: AI, through natural language processing (NLP), can provide context-based results, improving accuracy even with vague queries. This ensures students and instructors retrieve more meaningful content, regardless of exact keyword use.
- Personalized Results: AI tailors search outcomes based on user history and behavior, providing content that aligns with individual learning needs. For instance, if a student struggles with a concept, the AI can prioritize supportive materials.
- Voice and Conversational Search: AI chatbots enable natural language queries, offering instant, relevant resources, and making searches more interactive and accessible.
- Context-Aware Search: AI adapts search results based on user contexts, such as upcoming exams or recent performance, providing timely resources like study guides.
- Automatic Content Tagging: AI automates tagging with named entity recognition (NER), allowing for more precise and specific content retrieval.
- Multimodal Search: AI supports searching across different content formats (videos, images, text), accommodating diverse learning preferences.
- Error Tolerance and Suggestions: AI handles typos and ambiguities, offering suggestions to refine search queries for better results.
- Search Trend Analytics: AI analyzes search patterns, helping educators adjust content and improve learning experiences based on student needs.
- Metadata and Ontological Integration: By integrating AI with knowledge graphs, the LMS can organize content based on relationships between concepts, offering more in-depth and interconnected search results.

4. LMSs and AI integration

A detailed description of the overall architecture of an LMS that includes the full integration of generative AI tools with the traditional services provided by these platforms falls outside the scope of this brief discussion. In this section, we aim to briefly present the most radical transformations that the platform at our disposal is currently undergoing in light of what has been previously discussed.

The most significant modification relates to the persistence layer, specifically how educational content is stored. During the ingestion phase, this content is processed using tools predominantly based on deep learning, specifically graph neural networks. Our initial experiments have demonstrated that this variant of neural networks is particularly well-suited for identifying entities within the text. This structural change adds complexity to the content insertion phase because the content is no longer subjected to simple storage and keyword extraction, unlike in most existing systems. After storage, the content is represented as a graph, where nodes represent entities and edges represent relationships among them mentioned within the content itself. Figure 1 presents a general overview of the AI-based persistence layer that will constitute the repository of educational content in our LMS.

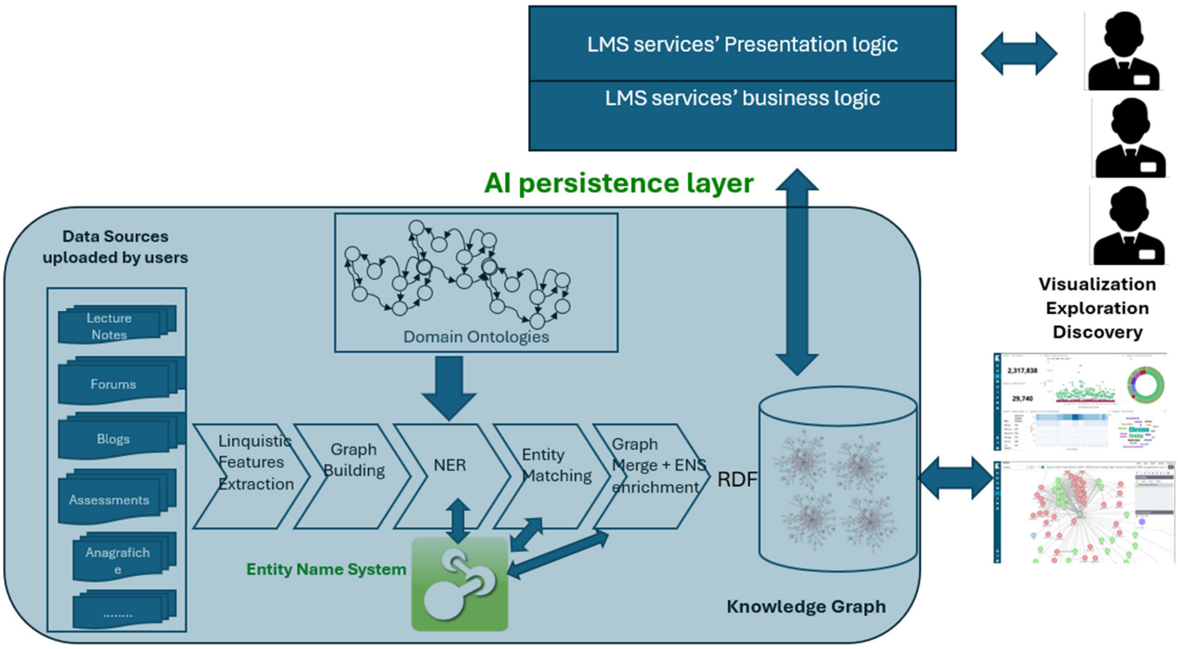

Fig.1 Conceptual view of the architecture of an AI-based persistence layer for an LMS

The central part of the persistence layer is a pipeline that will transform the LMS's data sources (textual contents of various origins) into an entity-centric knowledge graph. This transformation pipeline essentially tackles a series of highly challenging steps from both a scientific and technical standpoint, namely (fig.2):

1. Linguistic Features Extraction: through the process of linguistic features extraction, we identify relevant text elements and the involved relations
2. 2. Graph Building: a dedicated algorithm based on linguistic features (LF2G) transforms tokens and lemmas into nodes of an oriented graph
3. Named Entity Recognition: GNNs are used to recognize the semantics of an entity based on adjacent nodes and the type of relation between each other
4. Entity Matching: the Entity Name System [18] will be able to identify which nodes of the graph belong to the same entity.
5. Graph Merge + ENS Enrichment: the ENS will identify which nodes of the graph belong to the same entity.
6. Finally, knowledge graph creation and refinement: the single coming graphs of each document are merged into a Knowledge graph. An ontology developed for the specific domain can be used to refine results.

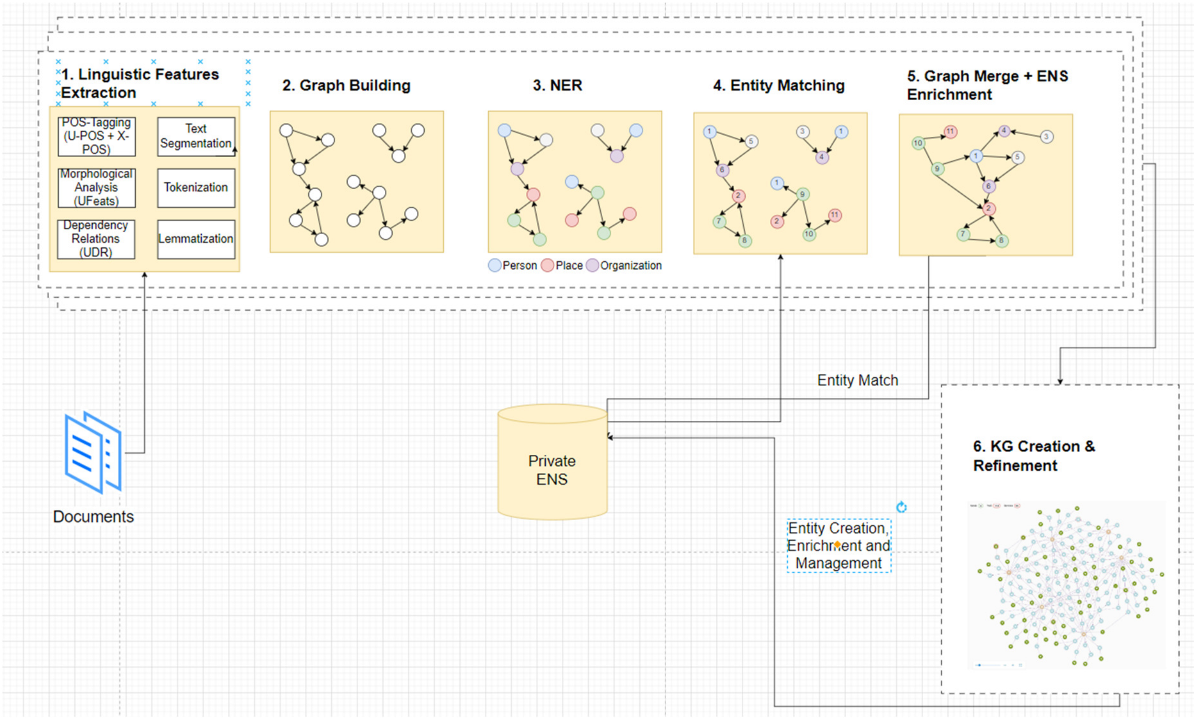

Fig. 2 The complete pipeline for textual content processing for an LMS

Among the complex steps that we are undertaking, we would like to evidence some elements, specifically devoted to how semantic technologies could be coupled with e-learning software. The early implementation revealed two of the most interesting aspects we wanted to test, i.e., the ease of implementing and/or new functionalities of a software platform when semantic technologies are wisely integrated with them. The idea is to put semantic technologies aside from traditional development technologies, identify content entities, and use persistent identifiers to store their unique ID from an entities' central repository called Entity Name System (ENS).

The ENS is a set of tools that supplies a persistent identifier to any entity included in the knowledge base, together with advanced entity-matching methods for detecting the occurrence of the same entity in different contexts and data sources. Once the entity in the LMS has been profiled by the ENS, it is possible to connect any content where the different occurrences of the same entity have been mentioned inside the LMS, thus facilitating the creation of the knowledge graph, and improving the quality of any search and inference process the LMS will provide to users. Another advantage is the possibility to connect any other content outside the learning platform where that entity has been named, for example, web pages or social network content, to the content in the LMS, applying the same NER mechanism.

Some further investigations emerged as necessary to achieve a clear vision of the pros and cons of this approach, specifically regarding sustainability and investments in re-factoring e-learning applications and general software applications. A second aspect that emerged from this research was the semantic persistence layers' performance. Intensive tests were conducted using the same big data-oriented technologies (Hadoop, Hbase, Flink, etc.) but in different contexts where a big data range of operation is required. As the results were encouraging, we conducted some preliminary tests with the knowledge base in our virtual community platform. Finally, the potential that AI-based technologies could provide for e-learning and collaboration is vast, but the problem here is the usability of content and services. Enriched by these semantic functionalities and contents, the risk is that they could become too complex to be understood and, therefore, unusable. A great help will come from semantic tools for data visualization and navigation.

Here follows a summary of the most challenging processes, in particular, graph building contains a set of different complexities derived from the nature of textual contents. One of the challenges is related to the problem of co-reference resolution for the Italian language. This process is subdivided into the following research areas and implementation.

- 2.1. Identify basic nodes: POS-Tagging identifies basic nodes of the graph, such as words tagged with NOUN, PRON, or PROPN
- 2.2. Enrich basic nodes with data properties: words tagged with ADJ are properties of one or more nodes. The dependency graph helps in identifying relations between words. For example, an AMOD relation (adjective modifier) can be used to assign a property to a node.
- 2.3. Co-reference Resolution, which is divided into:
  - 2.3.1. Merge nodes based on dependency graph: some kind of dependency relations that involve existing nodes can be used to merge them into a single logical entity.
  - 2.3.2. Identify co-references inside the same sentence: find all expressions that refer to the same entity in a text. For example, pronouns.
- 2.4. Identify relations: in verb phrases (VP) one or more subjects and one or more objects are related through one or more VERB-tagged words.

Fig.3 represents this part of the pipeline specifically dedicated to the construction of the graph. At the end of this pipeline, the new content (for the moment, textual content like blog posts, slides, lectures' transcription, forum contributions, evaluations, students' tasks, etc.) will be stored in the appropriate persistence layer: at the moment we are storing micro-graphs (single graph for single content) in a NOSQL repository, but for scaling and performance issues, we are evaluation to return to a traditional, relational database using a single table, multi-column, fact-table-like storage composed by the typical RDF triple (subject, predicate, object) with the addition of a graphID and a timestamp. From early experiments, the use of this storage structure seems to perform better than NOSQL solutions in the presence of ultra-large datasets.

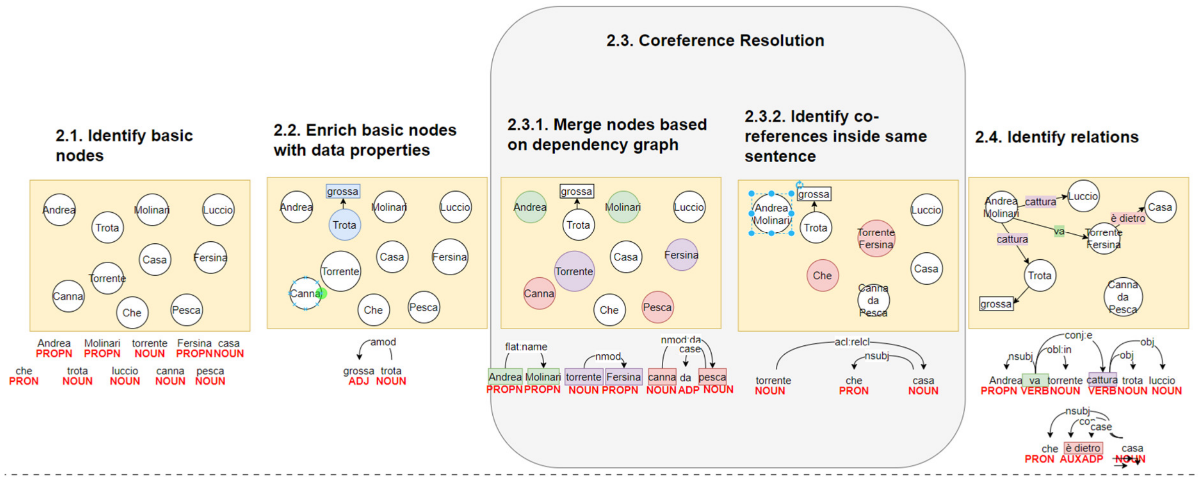

Fig.2 Construction of the graph related to an Italian sentence

5. Conclusions

The integration of AI into Learning Management Systems (LMSs) has the potential to significantly transform the management, delivery, and personalization of educational content. However, current implementations are limited by the underlying architecture of the most widely used LMS platforms, which were developed from the 1990s to the early 2000s and are based on relational database structures. These platforms lack the flexibility and adaptability required to fully leverage modern AI technologies, thereby constraining the potential of AI-driven tools to revolutionize education.

This paper introduces our ongoing research dealing with a foundational rethinking of LMSs' architecture, at least in their persistence layers, supporting the idea of a transition from traditional relational database models to graph-based systems that can support knowledge graphs and ontological frameworks. By making this shift, LMS platforms would be able to more effectively integrate AI functionalities such as semantic search, content recommendations, and personalized learning experiences. These improvements would not only enhance the user experience but also facilitate a deeper engagement with educational content, making learning more adaptive and responsive to individual student needs.

However, this vision presents some research and technical challenges. The proposed redesign requires a comprehensive overhaul of both the persistence and business logic layers of LMS platforms. The complexity of integrating multi-domain ontologies, which are essential for capturing the diverse and evolving nature of educational content, further complicates this transformation. Additionally, the need to train adaptive AI models that can respond to real-time content generation during periods of intense educational activity presents significant technological and HPC hurdles.

Despite these challenges, the potential benefits of this transformation are profound. A more AI-native LMS architecture would enable educators and institutions to harness the full power of generative AI, allowing for more dynamic, personalized, and efficient learning environments. As LMS platforms evolve, they must be designed to not only accommodate current AI technologies but to anticipate future developments in AI, ensuring that educational systems remain at the forefront of technological innovation. In conclusion, while fully integrating AI into LMSs is complex and requires significant structural changes, the long-term gains in terms of enhanced learning experiences, greater adaptability, and more sophisticated content management systems make this endeavor worthwhile.

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