

AI-Powered User Experience and Interactions with Galleries, Libraries, Archives and Museum (GLAM)

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Abstract

The integration of Artificial Intelligence (AI) techniques, including machine learning, knowledge engineering, autonomous intelligent agents, distributed AI, Natural Language Processing (NLP), and generative AI, is set to transform human-machine interactions. In parallel, advancements in User eXperience (UX) research, particularly in Virtual and Augmented Reality (VR/AR), or holographic interfaces, are enabling more intuitive and effective ways to engage with digital systems. This paper explores the transformative potential of the joint use of these technologies in the context of libraries and the broader GLAM (Galleries, Libraries, Archives, and Museums) sector.

This paper discusses these innovations alongside real-world use cases from the GLAM sector, currently being developed at the University of Geneva. They illustrate how AI-powered solutions combined with UX techniques are reshaping the way we interact with cultural and scientific knowledge, making it more accessible, engaging, and impactful for diverse audiences. While opening many opportunities, these AI-based systems face several issues. We thus complement the discussion with a critical analysis of challenges and limitations encountered when developing such systems.

Key words

AI, Knowledge Graph, Ontologies, NLP, Intelligent Conversational Agents, User Experience, Data Visualisation, Deep Learning, Knowledge Federation, Archives, GLAM



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1. Introduction

Artificial intelligence techniques such as : machine learning (Russel & Norvig, 2021), Knowledge Engineering (Ryś, Lima, Exelmans, Janssens, & Vangheluwe, 2024) (Falquet, Mottaz, Jiang, & Ziswiler, 2004), Autonomous Intelligent Agents (Wooldridge, 2009) and Distributed AI (Russel & Norvig, 2020), Natural Language Processing (NLP), as well as Generative AI (Sengar, Hasan, Kumar & Carroll, 2024) have come to the fore recently. In parallel, research on User Experience (UX), including Virtual and Advanced Reality (VR / AR) (Hillmann, 2021) aims at providing innovative and efficient human-machine interactions.

Galleries, Libraries, Archives and Museum (GLAM)¹ hold a tremendous level of knowledge: scientific articles, books, entire encyclopedia, or cultural artefacts; provided under various media formats such as: text, images, audio, video or physical objects, structured or semi-structured data, geo-spatial data, etc. Despite digitalisation, researching information through a set of entries in such various formats (e.g. identifying similarities, or links among entries), through a library, or even among several libraries, remains a difficult - mostly manual - task for a reader. On the librarian side, cataloging and classification still remain laborious tasks. Additionally, despite digitalisation, readers are deserting libraries which need re-inventing (The Carlson, 2001) (Labo Société Numérique, 2022).

The advent of both AI and UX offers an opportunity to reinvent the GLAM sector, to reconnect with readers or visitors, providing innovative and efficient AI-powered User Experience. On the one hand, AI helps GLAM specialists in their day-to-day tasks, such as automating cataloguing and classification; providing 24/7 library services (timetable, available resources, personalised recommendations); or optimising collections with data analytics. On the other hand, along with digitalisation of corpuses, AI and UX will revolutionalise the way scientists, students or visitors interact with artefacts, articles, books, entire corpuses, libraries, or individual entries in encyclopedia, independently of the media format.

Based on a digital innovation process we set up at the University of Geneva, we develop here our vision for an AI-powered User Experience with GLAMs. We will focus on two main aspects, both illustrated with ongoing work at the University of Geneva: (1) interaction and dialog with corpuses; (2) uncovering information from research data. The combination of promising AI and UX technologies, along with useful knowledge representation, helps exploring a library, visiting exhibitions and museums, connecting various sources of information, uncovering new information, and presenting the result in a visual interactive manner. While promising and opening many opportunities, we also highlight challenges and limitations of these technologies.

2. Related works

We present here a series of works in various GLAM domains with a focus on some AI and UX technologies.

2.1. Linked Data and the Semantic Web

The project **nomisma.org**, initiated by the American Numismatic Society in 2010, leverages **Semantic Web** and **Linked Open Data** to facilitate the online presentation of numismatic concepts. This approach establishes a robust framework for machine-based data exchange

¹ <https://wikimedia.ch/fr/programmes/glam/>

between systems. Tools like **Online Coins of the Roman Empire** (OCRE, n.d) and **Coinage of the Roman Republic Online** (CRRO, n.d.) now enable both coin cabinets and archaeological inventories to exchange and publish data seamlessly online.

Wigg-Wolf and Duyrat (2017) discuss the ontology underlying various numismatic case studies, in particular data structures underpinning Greek coinage studies, and how the technology and insights from **nomisma.org** are adaptable for other archaeological datasets.

2.2. Generative AI and Visitor experiences

Generative AI is unlocking new possibilities for cultural institutions, particularly in enhancing visitor experiences.

- **Exhibition Example:** At the Louvre Abu Dhabi's exhibition "*De Kalila wa Dimna à la Fontaine, voyages à travers les fables*", visitors use generative AI to craft personalised fables. They can select writing styles, characters, and morals, creating unique stories tailored to their preferences (Clergeau & Karouby, 2024).
- **Cultural Opportunities and Challenges:** Generative AI expands opportunities for **scientific mediation**, **artistic creation**, and **collection valorisation**. However, challenges include ensuring data quality for training AI models and maintaining alignment with mediation regulations (Clergeau & Karouby, 2024).

In media and creative industries, generative AI is driving innovations such as AI-written movies and music production. Research highlights the importance of advanced data visualisation and optimising environmental impacts of AI applications (Amato et al., 2019).

2.3. Personalised Agents

Personalised conversational agents are revolutionising how museums interact with visitors, offering dynamic and tailored experiences.

- **Visitor Personalisation:** Traditional immersive technologies like mobile apps, audio podcasts, and digital maps offer predefined exploration paths. By contrast, conversational agents provide an **interactive and customised journey**, addressing the diverse needs of visitors (S. Rey et al., 2020).
- **Projects in Action:**
 - The **British Museum's "The Living Museum"** (Talmi, 2024) employs AI-driven conversational agents, enabling engaging interactions with exhibits.
 - The **Musée national des beaux-arts du Québec** integrates similar technologies to enrich visitor experiences. (Musée national des beaux-arts du Québec, n.d.).

2.4. InterPARESTrustAI

The InterPARESTrustAI (n.d.) project aims at identifying AI technologies for addressing critical records and archives challenges. Research evolves around various themes, e.g. AI tools for processing and managing public records, reconstituting archival aggregations, health and patients records, or Maturity frameworks for appraisal processes (Makhlouf Shabou, 2024). Investigated technologies range from NLP, Knowledge engineering, Generative AI and digital twins.

Across the GLAM sector, AI and UX technologies are reshaping how information is exchanged, cultural content is experienced, and records are managed. From numismatics to museums and archival systems, these technologies are fostering innovation while addressing critical challenges in data quality, environmental sustainability, and user engagement.

3. Vision

To embrace modernity and deliver innovative services, our approach brings together key stakeholders to align around shared goals. This collaboration enables us to actively drive the transformation of our institution while prioritising exceptional user experiences and educational outcomes for our students. In the sections that follow, we outline our digital innovation process and develop our vision for the GLAM sector.

3.1. Digital Innovation process at the University of Geneva

We set up at the University of Geneva (Unige) an innovation process aiming at developing innovative digital services for the University. This unique process follows a service science approach (Di Marzo Serugendo & Friha, 2021), where researchers, students, information systems experts and stakeholders' team up to ideate services, develop ideas into functional prototypes, and industrialise and deploy them for the whole University community. This innovation process is a funnel, where some of the produced ideas are transformed into prototypes and the most promising prototypes are turned into an industrial service.

As part of this digital innovation process, we regularly coach students and manage innovation projects. With the recent development in Generative AI, in particular text analysis, we are brought to investigating GLAMs (Galleries, Libraries, Archives, Museum) related projects. The University of Geneva as well as external organisations have their own archives, data to be processed, or research data repositories, most of the time all of them available as open data. Such stakeholders are now interested in better understanding their archives, visualising their content in innovative ways and possibly interacting with them.

3.2. A knowledge centric approach using latest AI techniques maximizing User eXperience

Nowadays we deal with huge, complex and evolving datasets coming from heterogeneous sources, format, storages and representations. Our vision to explore and exploit this data is to provide a *knowledge-centric approach by bringing together advanced Artificial Intelligence (AI) and User eXperience (UX) techniques*. Such new and innovative services support interaction with knowledge while maximising user satisfaction.

Several *advanced AI disciplines* put together contribute to achieving these objectives: Machine Learning for providing predictions, classifications or clustering on diverse types of data (quantitative, qualitative, figures, etc.); Natural Language Processing for extracting information from textual documents in various languages, including the generation of summaries or translations; Semantic AI or Knowledge engineering for developing ontologies and providing meaning to data; Generative AI for generating texts or images; Retrieval Augmented Generation (Gao et al., 2023) complements Generative AI-based services in retrieving most pertinent information or data sets on which to generate an answer in response to a user query. Multi-agent systems for organising a service into specialised coordinated tasks, while providing autonomous behaviour. Finally, Large Language Models (LLMs) are deep learning machine

models based on large corpus datasets designed for natural language processing tasks (e.g. language generation).

Similarly various *User eXperience techniques* participate to our vision: Conversational agents or Chatbots allow a fluid interaction with users mimicking human discussion; Augmented reality connects physical and virtual world by superimposing information on actual reality; Virtual reality offers 3D interactive or immersive visualisations; Multi-sensory technology, e.g. haptic gloves and devices that stimulate senses (touch, smell) help create more immersive experiences, finally Holographic interfaces enable active 3D interaction from participants.

Figure 1: AI and UX technologies toolkit

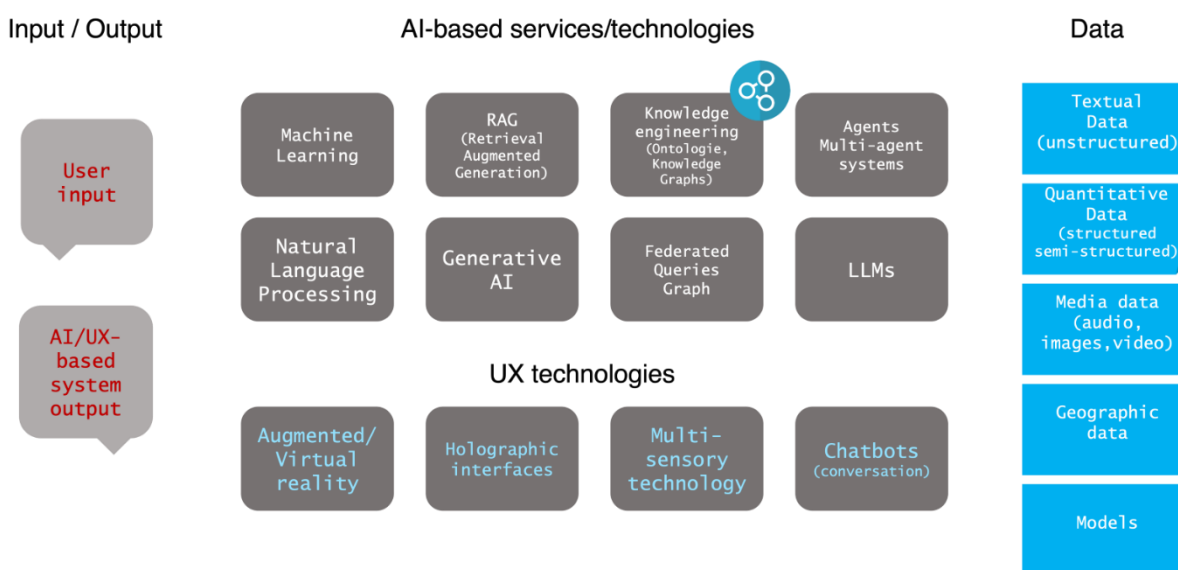


Figure 1 summarises some of the data sources, AI and UX technologies discussed in this paper.

3.3. Possibilities

The combination of both AI and UX techniques leads to innovative services centered on knowledge issued from GLAMs. Together they offer a wide range of possibilities: (1) facilitating access to knowledge (e.g. easily retrieving and presenting information); (2) personalising interactions based on the user profile (teacher, student, child); (3) favouring shared findings from different disciplines (e.g. performing correlations, identifying similarities); (4) asking for summaries, for additional scientific or simplified explanations; (5) body-based interactions using natural language (oral, written – prompt-based approach), or other senses such as touch (hands), sight or smell (Xperienz, 2024).

4. Interaction and dialog with corpuses

Conversational agents, be they more traditional ones or equipped with Generative AI, open up the possibility to directly “discuss” and interact: (1) with a library entry (e.g. a book) to get a summary, or to ask questions and clarifications about specific points; (2) with a contemporary author to get her viewpoint on a book (Comtesse & Pauletto, 2023); (3) with a past author - or more likely in that case with a specialist of the book and author in question - to provide background information, interpretation or links with other books. Companies are now specialising in this type of interaction (Hestia.ai, n.d.).

When researching a specific domain for hobby, work, study or research, we imagine extending the above type of interaction and discussion to a whole library. For instance, one may be interested in finding out all the different ways for designing a car motor (steam, gas, electricity, hybrid, other), their history, trends, including economic issues. The reader smoothly navigates through the various library entries. Visualisation of results and information are comprehensively provided during this guided tour, exploiting the various media available.

This automatically brings additional possibilities to interact with, retrieve or uncover information. Let's take a fun example, such as completing a cooking recipe with missing ingredients or just replacing it with another one due to allergy. The virtual librarian could explore a range of cooking books, social networks, videos, to provide the most appropriate advice to the user (e.g. replacing coffee with apple juice in a Tiramisu, or eggs with yogurt in a cake).

In the following, we describe several use cases developed or ongoing at the University of Geneva, all supported by the digital innovation process described above, all aiming at interacting and dialoguing with corpuses.

4.1. Discussing with a scientist

We have recently been challenged by scientific colleagues in another discipline to provide a holographic representation of a former (deceased) well-known professor, and to complete this representation with a fluid interaction consisting of a discussion with a fellow contemporary researcher about specific scientific topics. Such an achievement requires two distinct aspects: (1) "reviving" or providing a realistic holographic representation of the person from archive media such as audio, video or photographic images; (2) exploiting further archives and research data for nourishing the interactive scientific discussion. We currently have two teams of students working on this subject. One of them, Aaron Gogniat, Sébastien Julien Conicella, Selma Dali, Ines Dali, and Yasser Takarli (2024, Autumn) explored preliminary innovative approaches to interactive avatars.

To achieve the first part (holographic representation), we will extensively use several of the latest Generative AI services available today. First, from audio files, we need to provide a realistic generated voice of the person able to emit pre-defined sentences of our choice or generated ones derived from the discussion. Tools such as Whisper (OpenAI, 2022) handle such tasks. Second, based on photographs or videos we must create the equivalent of a deepfake video where lips movement synchronise with the sentences. Tools such as Wav2Lip provide such services (Prajwal, Mukhopadhyay, Namboodiri, & Jawahar, 2020). Third, we need to combine this with body movements (e.g. using DeepMotion (n.d.)). When everything is integrated, we finally create a hologram (e.g. following techniques such as Creative SL, 2022).

To achieve the second part (interactive scientific discussion), we will use existing LLMs for e.g. LLAMA (Meta, 2024) for generating the answers to some questions provided by the fellow contemporary researcher and prepare the context for the answers with papers, theory, research results or any documents our scientific colleagues deem relevant for this discussion.

Figure 2: Interaction with a holographic representation of a scientist

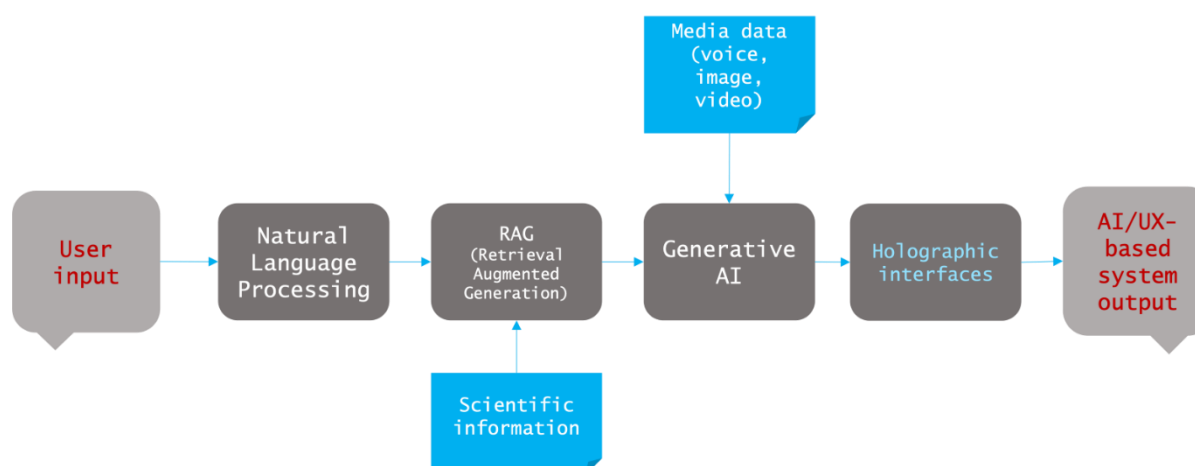


Figure 2 depicts the workflow of the above example, where a fellow scientist asks orally a question (User input), which is then processed by various AI-based tools, in this case Natural Language Processing for interpreting the question, and Retrieval Augmented Generation (RAG) for retrieving the most pertinent documents among the corpus of all scientific information available. The system then first generates an answer and second processes the media data corresponding to the deceased professor to generate the appropriate 2D sequence including voice and images corresponding to the answer. Various Generative AI services will help with these two tasks. Finally, the UX holographic interface module provides the holographic representation, which once enacted constitutes the answer to the original question (AI/UX-based system output).

4.2. Digital twin of an archeological site

Colleagues from the department of Ancient Archeology set up an exhibition, Immersum project, running from December 2024 to February 2025 (Université de Genève, n.d.) about an underwater archeological site in Greece, located at the Bay of Kiladha. On this occasion, we investigated together various possible interactions between visitors and the exhibition artefacts. Starting with a set of data acquired through various means: data acquired underwater by archeologists in non-digital format, digital geographic data, bathymetric data, photogrammetric data and Google Earth and satellite data, we could reproduce a 3D digital model of the site, acting as a static digital twin. From the same set of data, we provided a 3D printed scale (physical model) enhanced with an animation showing water progressing over the last 150K years. Finally, by inserting this data into tools such as Unity or Blender, a group of students (Mallem, Michaud, Joannin, Pereira, & Bonaz, 2024) provided 3D interactive user experience service, in which a visitor can move within the site and explore the site (like in a video game).

Digital twins are digital representations of a physical twin, in this case here an archeological site. This collaboration with our archeology colleagues opens the door to further research into the notion of a “digital twin of an archeological site”. The 4 levels of digital twin (Di Marzo Serugendo et al., 2022) we identified can be applied to such cultural artefact: (1) 3D digital or scale model act as *static digital twin* (Level 1); (2) adding functionality to this twin leads to a *functional digital twin* (Level 2) where the behaviour of the site enables to recreate the past or predict future status of the site; (3) adding real-time data to the functional digital twin provides

a *real-time twin* (Level 3) informing the site curators about the current situation underwater; (4) combining the previous twin with an intelligent agent provides an *intelligent twin* which can perform various tasks, such as discussing with a visitor, giving information, alerting curators if anything urgent needs attention.

Figure 3: Static Digital Twin of the Bay of Kiladha

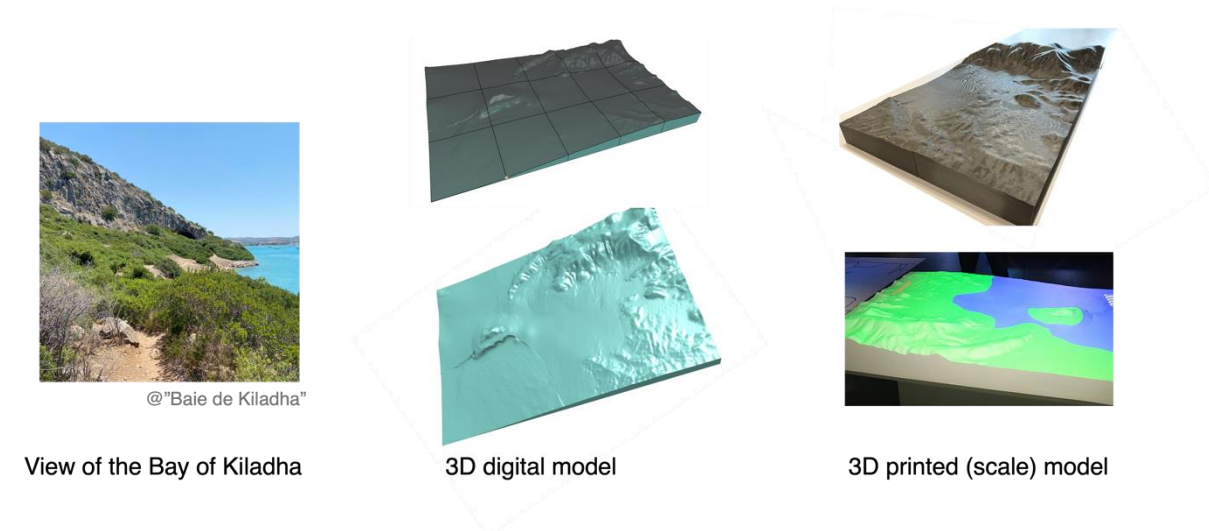


Figure 3 shows on the left an actual view of the Bay of Kiladha where the underwater archeological site is located. In the middle we see two views of the 3D digital model built thanks to the various data discussed above. Finally, on the right we see the 3D printed scale model obtained from the same set of data. The bottom right image shows the light illumination (in blue), projected on the 3D scale model, indicating the level of the water at different time periods.

Digital twins of archaeological sites represent a transformative tool for both scientific research and education by leveraging advanced technologies to create 3D virtual and physical reproductions of historical locations. These digital replicas allow researchers to navigate sites from multiple angles and even simulate conditions from different periods of time, offering unprecedented insights into historical contexts. By filling gaps in incomplete records with generative AI, digital twins can reconstruct missing features and provide a more comprehensive understanding of ancient environments. This approach aids in studying climate evolution over millennia, uncovering geological phenomena, and visualising paleo-landscapes, thereby deepening our knowledge of both natural and human history.

Additionally, digital twins hold immense potential for museums and exhibitions within the GLAM (Galleries, Libraries, Archives, and Museums) sector by enabling interactive and immersive educational experiences. Visitors can explore virtual reconstructions augmented by interactive explanations, enhancing engagement and making complex scientific findings accessible to a broader audience. These innovations not only enrich archeological research but also democratise access to cultural heritage, fostering greater appreciation and understanding of the past.

4.3. Interacting with an archeological/museum artefact

Building on this concept, a complementary ongoing MSc project focuses on developing intelligent digital twins that act as agents representing specific artefacts, such as castings of

Ancient Greek and Roman statues. These conversational agents are designed to provide visitors with personalised, interactive experiences. They act as assistants, offering tailored explanations about the artefact's history, context, and connections to other works. A visitor can explore a 3D digital replica of an artefact, engage in a dialogue, and even uncover relationships with other pieces in the collection. When relevant, intelligent digital twins of related artefacts can dynamically join the conversation, enriching the visitor's understanding and fostering a deeper connection to the collection.

Figure 4: Interaction with a museum artefact

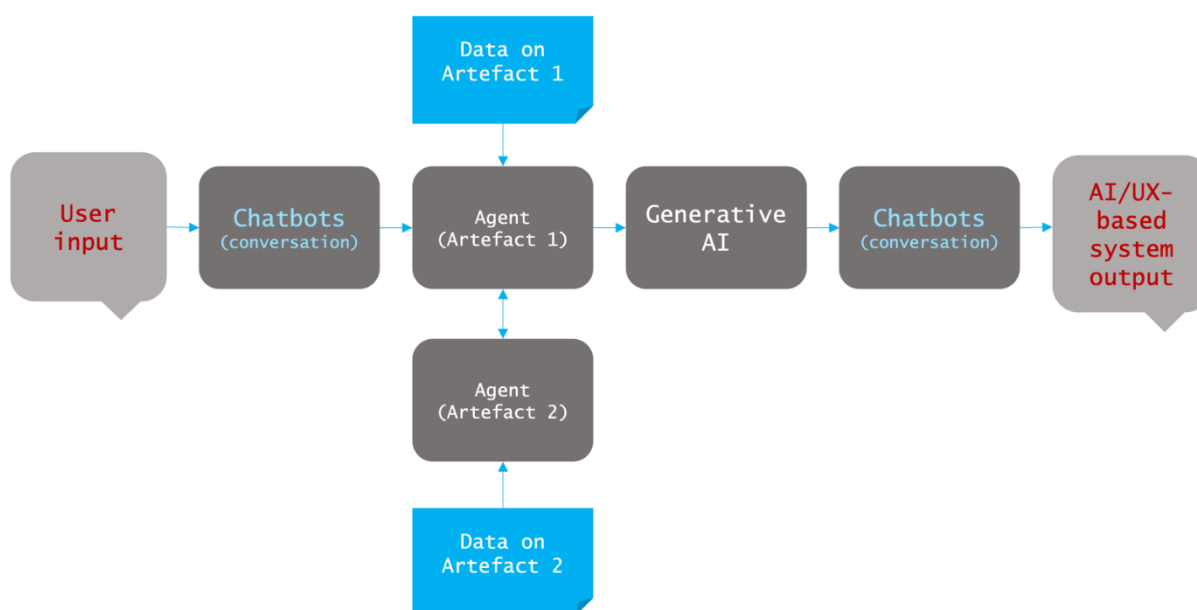


Figure 4 shows the workflow that allows interaction with a museum artefact. Starting from an initial query from the visitor (User input) about Artefact 1, and through a conversation through a chatbot UX interaction, the intelligent agent working on behalf of Artefact 1 receives the query and processes an answer based on data it holds or retrieves on Artefact 1, potentially involving the intelligent agent of other artefacts, e.g. Artefact 2, for further complementary details. Once the content for an answer or a discussion with the visitor has been established, a Generative AI module formulates the answer (in written form or orally), which then constitutes the AI/UX based system output.

This approach not only revolutionises how artefacts are presented but also allows users to discover collections from a fresh perspective. By "giving life" to the artefacts through conversational agents, visitors gain a unique opportunity to ask questions, engage in discussions, and immerse themselves in the stories of these historical works. The result is a system that merges cutting-edge technology with cultural education, making the past more accessible, interactive, and engaging for diverse audiences.

4.4 Exploring and analysing archives

As part of an ongoing MSc project, we are studying how to explore, investigate and make sense of open data archives. We started from the observation that most archives, even though digitised and made accessible online, annotated following proper archival methods, remain difficult to investigate. Some archives are scanned manuscripts documents, that in some cases remain difficult to decipher even for AI-based services, others are produced with a typewriter,

or more recently are actual digital native documents, thus easier to process with a computer program. They may also contain images or drawings that provide additional knowledge.

We are currently focusing on the United Nations archives available online, which contains more than 270K documents (United Nations Archives, n.d.) of different nature dating back to the early 19th century. Our approach mixes Generative AI and Semantic AI and follows these steps:

1. Extract information from typewritten or digitally native documents
2. Exploit the UN ontology, called UNDO (United Nations System Chief Executives Board for Coordination, n.d.) and create a knowledge graph of data extracted from the archives that follows the ontology of the archives in question. This includes references to other documents, people, organisations, legal terms, roles, and deliberation steps. It helps in structuring and standardising the information contained in UN documents and hence facilitates management and retrieval.
3. Query and explore the archives to help either an archivist to order documents in chronological, alphabetical order or by thematic subject (e.g. UN discussions on a dedicated theme); or an historian to match letters or documents together, or to find answers to some research questions.
4. Use Generative AI for: (1) extracting information from the documents according to the ontology; (2) creating a knowledge graph populated with the data extracted from the documents following the ontology; (3) transforming a user query expressed in natural language into a SPARQL query; (4) providing a result expressed in natural language for the user.

Figure 5: Interaction with UN archives

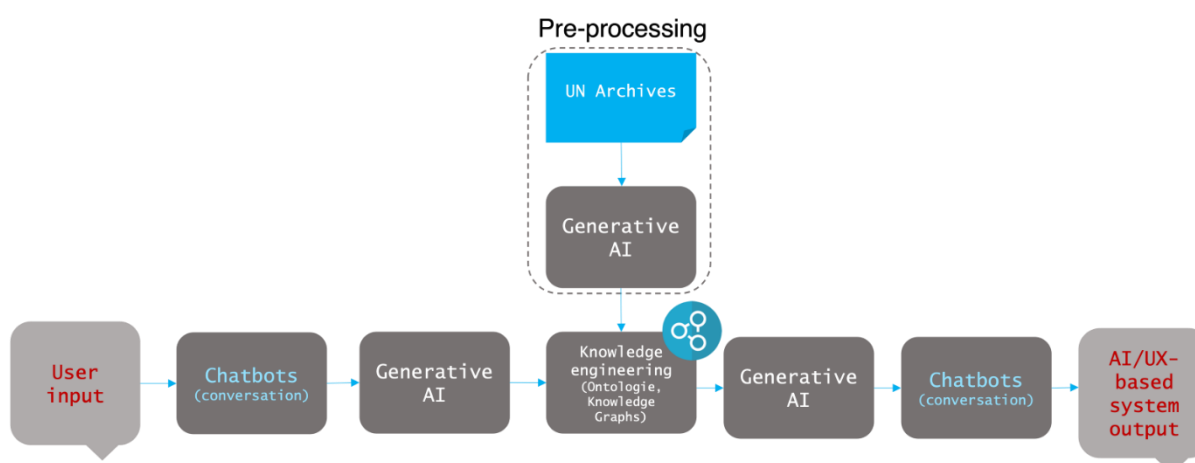


Figure 5 highlights the interaction with the UN archives. Similarly to Figure 3, a UX chatbot conversation is captured by a Generative AI module that translate the question (User Input) into a SPARQL query addressed to the knowledge graph containing relevant UN archives information stored as triples following the UN ontology. The result of the query is then further processed by a Generative AI module for providing an answer expressed in natural language understandable for the user. We need a pre-processing phase, where documents of information of UN Archives are extracted in accordance with the UN ontology and stored in the knowledge graph.

We plan to later extend our work to other scientific archives from the University of Geneva, the French library (BNF - bibliothèque nationale de France (Bibliothèque nationale de France, n.d.), or the documents containing the minutes of the Grand Council of Geneva Canton (Grand Conseil) since the year 2000 (Grand Conseil de la République et canton de Genève, n.d.).

5. Uncovering information from research data

FAIR principles (Wilkinson et al., 2016) and Open Science (UNESCO, 2022) drive today the provision of research data and results. The aim is to widely share knowledge issued from research data among scientists, students and the public. AI is particularly useful for supporting interoperability and re-usability of research. For instance, researchers can replay scientific experiments. Instead of reading a “flat” scientific paper (i.e. a PDF), the reader can replay the authors’ experiments - from within the scientific paper - to understand how they unfold, what happens with different initial data, and she can even try out the experiment with her own data (Masselot, 2019).

For the public, these smart tools act as Intelligent Discovery Assistants, giving each citizen: (1) a great opportunity to search, learn and discover scientific knowledge from the same data sets as scientific researchers; (2) provide a personalised explanation at the appropriate technical level. Additionally, the assistant hides complexity, fine-tunes the user query through the conversation and learns to adapt to user needs (context-aware query based on user profile, research context, etc.). The assistant composes the user query using advanced prompting techniques to facilitate user interaction.

In the following, we describe first several institutional services developed at the University of Geneva for exploring research data, then some use cases, highlighting the potential of research data, developed in the framework of the digital innovation process described in Section 2.

5.1. Exploring research data

The University of Geneva is a pioneer in offering advanced digital infrastructure and service allowing to leverage scientific research data in Switzerland, de facto supporting FAIR principles and Open Science. Based on well-known standards and protocols, these services are as follows:

Hedera² is a digital infrastructure designed to host and maintain active research data through digital humanities standards: [RDF](#) for metadata, and [IIIF](#) for sharing visual assets. Both formats operate by accessing assets through URIs, which facilitates the interoperability of visual assets with their metadata, as well as the sharing and interlinking of different datasets.

Yareta³ is the Research Data Repository for Geneva's Higher Education Institutions. This is the place where most research data is stored and made available.

OLOS⁴ is a Swiss-based data management portal tailored for researchers and institutions. Powerful yet easy to use, OLOS works with most tools and formats across all scientific disciplines to help researchers safely manage, publish and preserve their data.

² [hedera - eResearch - UNIGE](#)

³ [Yareta - eResearch - UNIGE](#)

⁴ [Home - OLOS: The Swiss solution for managing research data - UNIGE](#)

Knowledge graphs (KG) and ontologies capture domain knowledge to which research data belongs. They provide the chance to connect and identify relationships across diverse knowledge domains, leading to new insights. KG and ontologies enhance federated searches across multiple graph databases. Additionally, interactive visualisation allows for the discovery of new patterns within complex and large research datasets.

We describe below first how knowledge engineering and ontologies are crucial for research data and proceed then with two examples exploiting respectively knowledge graphs and ontologies, and interactive visualisation. They highlight the potential for scientists, students or the public to discover new knowledge from research data.

5.2. Highlighting the power of Knowledge Engineering

Knowledge engineering plays a pivotal role in modern information systems by enabling openness and interoperability across diverse data sources. Using standardized semantic frameworks such as ontologies, it facilitates the creation of common descriptions that can be easily shared and understood among various stakeholders and systems. This approach not only federates knowledge across distributed repositories but also enhances it by connecting disparate datasets into a unified, enriched network of information. By providing a structured foundation for representing and organising knowledge, knowledge engineering makes it easier to leverage advanced technologies such as generative AI and multi-agent systems, unlocking new possibilities for dynamic reasoning, collaborative problem-solving, and innovative applications

Moreover, UX interactions combined with knowledge engineering supports the development of a variety of cutting-edge services, including semantic search engines, chatbots, and smart agents, which enable natural language-based exploration and interaction. In addition, augmented and mixed reality experiences can integrate this knowledge to offer immersive and intuitive ways to discover new information, enhancing both user engagement and the potential for uncovering previously inaccessible insights.

5.3. Medical/Pharmaceutical knowledge exploration

Several application areas benefit from the integration of Knowledge Engineering and advanced User eXperience allowing effortless interaction with large datasets and finding relevant information, recommendations and discoveries.

One of the promising and challenging works carried out as part of two joint master theses, by our students (Sedoh, 2023) (Guetarni, 2023) addresses the crucial issue of drug interaction. The idea is to first capture knowledge on drug, drug interactions and the medical field through ontologies. An intelligent agent then exploits this knowledge to answer questions on: (1) drug-drug interactions, (2) drug-food/beverage interactions and (3) drug-patient's condition interactions. Unintended drug interactions can have unexpected side effects (e.g. be harmful to the patient), it is then important for the patient to be able to check those interactions, possibly on her own, at any time.

The study has shown that moving from existing static websites - containing the information but difficult to read or to correlate information - to advanced knowledge representations that can federate and link open data, provides more relevant warnings and pertinent information to patients and health personnel.

The following chat with Pharmabot shows that it can understand user intentions. It can check for interactions between two drugs, allowing the user to specify the variant of the drugs in question (Figure 6). It detects entities corresponding to drugs and respond to user needs by making requests to the knowledge graph and give accurate answers to users who want to know whether a drug has an impact on driving, whether it can cause allergies (Figure 7), and even whether it is considered a doping product.

Figure 6: Example of interaction with PharmaBot (incompatibility between two drugs)

Chat avec Pharmabot

Que puis-je faire pour vous ?

peux tu vérifier les interactions avec mavenclad ?

Vouslez préciser le médicament dans la liste suivante:

Le médicament **MAVENCLAD cpr 10 mg** a bien été ajouté ✓

Souhaitez-vous ajouter un autre médicament ?

Oui

Entrez le nom du médicament

Vouslez préciser le médicament dans la liste suivante:

Le médicament **FUCIDIN cpr pell 250 mg** a bien été ajouté ✓

En pleine recherche...

J'ai trouvé les informations suivantes:

- **Contrainte:** CONTRE-INDICATION
- **Description de l'association:** Par voie orale ou rectale du sorbitol ou de la résine, et pour une dose de sorbitol par prise >= 2,5 g chez l'enfant et 5 g chez l'adulte : Risque de nécrose colique, éventuellement fatale.

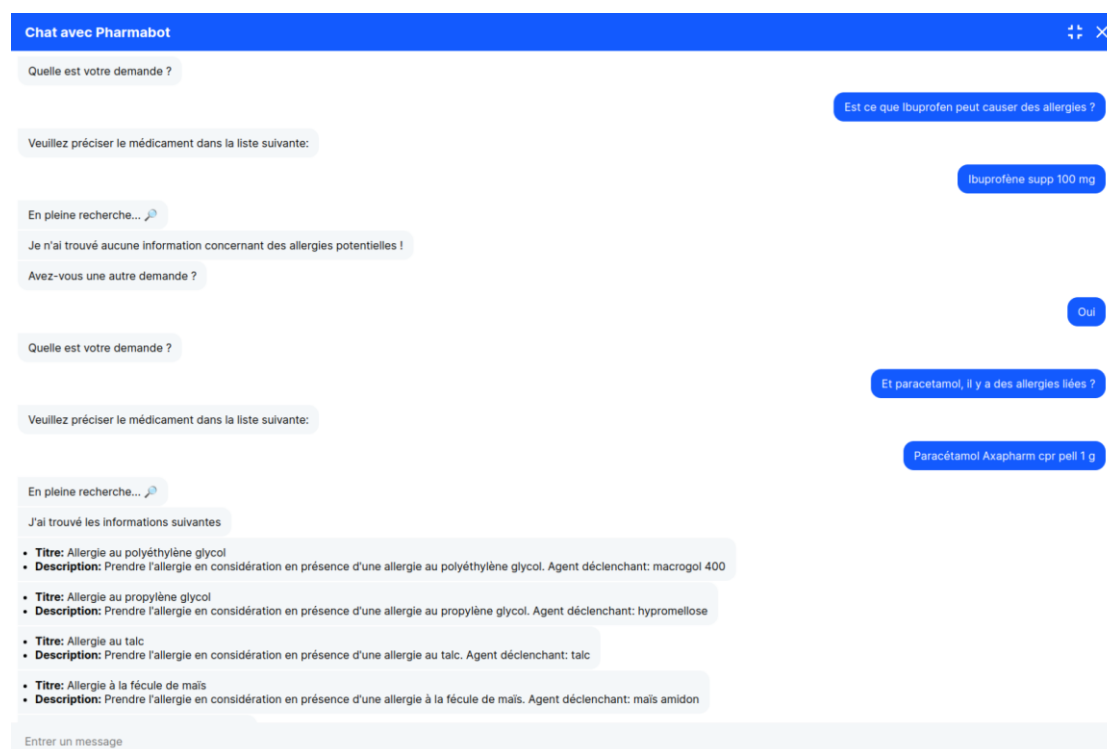
Est ce que je peux vous aider autrement ?

Oui

Entrer un message

(Sedoh, 2023) (Guetarni, 2023)

Figure 7: Example of interaction with PharmaBot (warnings for allergies)



(Sedoh, 2023) (Guetarni, 2023)

5.4. Revealing information through interactive Data visualisation

Innovative data visualisation tools allow smart interactions, augment the ability of understanding and analysing complex relationships in large and federated datasets, in particular research data.

Future intelligent agents will be capable of producing and generating advanced visualisations. Alternatively, they can also be prompted from within a visual diagram for further analysis or complementary information provided by specific GLAM corpuses or research datasets.

One of the uses cases developed at the university of Geneva is an advanced visual tool, based on the Sankey diagram (Bostock & Observable, n.d.). It allows future students to discover and explore the career paths of graduate students five years after graduation and to ultimately guide professional and academic choices (Figure 8). The visualisation is further complemented with audio or video interviews of graduated students.

[illegible]

Nowadays data has become crucial for feeding new innovative services based on AI technologies. However, it presents various challenges to be used effectively. It is important to ensure that it satisfies the main criteria such as quality, diversity, accuracy, relevance, interoperability, security and volume and has been collected ethically. A large palette of tools, technologies and frameworks have been developed to prepare data to be used: (1) data representation based on universal standards such as RDF, JSON; (2) Extract Transform Tools (ETLs) such as Talend; and (3) Fairness indicators tools to minimize bias and data governance policies. Besides AI technologies help improve data quality (removing duplicates, augmenting data, cleaning data, automatic training using subsets of data).

- Structured data such as Relational databases
- Unstructured data such as Pdf documents, textual documents, images, voices
- Semi-Structured data such as JSON, XML, etc.
- Media data (audio, video, images)
- Geographic data such as satellite data, photogrammetric or bathymetric data
- 2D or 3D digital models

Challenges around data encompass not only crucial issues such as *quality* for accurate results and *quantity* for relevant learning and training but also *ethical considerations* such as bias or *changing and evolutive data* that requires re-training, consolidating or fine-tuning the system.

Besides data, challenges of AI-based systems include *privacy and security* to protect both individuals and their data. *Legal and copyright aspects* are also essential in the digital age, and currently legal frameworks for AI-based systems are only at their infancy.

Additionally, important limitations should be considered to develop effective solutions such as: *costs* associated with developing (e.g. need for a local computing infrastructure, and its energy consumption), *maintenance* since AI-based systems requires continuous monitoring and adaptation.

7. Conclusion

In the movie "The time machine", the librarian "Vox 114", a holographic assistant interacts with the main character Dr Alexander Hartdegen (Movieclips, 2012). Nowadays it is possible to conceive such a smart chatbot provided as a holographic representation, to guide and help as a librarian would do. In the use cases described in this paper, various AI and UX technologies, such as knowledge engineering, natural language processing (NLP), mixed reality, or holographic representations come together to maximise user experience, provide personalised recommendations, and deliver results combining various data sources.

Current advances in AI and UX make it possible to imagine a future for libraries where both librarians and users benefit from all the available corpus of information and their inter-relationships, uncovering hidden links or correlations, ultimately experiencing innovative interactions with entire libraries.

For tackling these problems, we envision the future of these innovative solutions within a distributed approach, which reflects the distributed nature of the underlying real-world problem. Multi-agent systems are the best way to explore archivist uses cases in a distributed manner. A PhD thesis is starting on this issue and is a collaborative project between the University of Geneva and the Haute Ecole de Genève (HEG).

More generally, we intend to pursue the combined usage of Knowledge Engineering (ontologies and knowledge graphs), Generative AI, and multi-agent systems. Digital twins share many similarities with multi-agent systems and are naturally well-suited to incorporate various AI and UX technologies for benefit of the GLAM sector.

In conclusion, the integration of Artificial Intelligence (AI) techniques and advancements in User eXperience (UX) research are set to re-invent human-machine interactions. Real-world use cases from the GLAM sector, developed at the University of Geneva, demonstrate how AI-powered solutions are reshaping the way we interact with cultural and scientific knowledge. These innovations make information more accessible, engaging, and impactful for diverse audiences. This new era of digital systems as active partners in knowledge dissemination and valorisation highlights the evolving role of libraries, galleries, archives, and museums in contemporary society.

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