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The potential of generative artificial intelligence in the digital representation of military history collections

Introduction

In today's world, digital technologies are significantly changing approaches to the preservation, presentation, and study of cultural heritage. Of particular importance is the creation of virtual museums and digital exhibitions, which provide a wide audience with access to historical and cultural artifacts regardless of geographical location.

Military history collections – weapons, armor, artifacts from military campaigns – are particularly valuable because they reflect the history of statehood, the development of military technology and traditions, and shape the collective memory of society. In the context of the Ukrainian-Russian war of 2022–2025, digital platforms are becoming even more important as a tool for shaping patriotism and national identity among young people.

Generative artificial intelligence (AI) opens up new opportunities for virtual museums, allowing them to create interactive exhibitions, reconstruct damaged or lost artifacts, form personalized narratives, and provide dynamic content for users. This approach not only contributes to the preservation of heritage, but also actively engages the public in history, making it more accessible and understandable.

Related work

Foreign historiography

The global scientific community has been actively researching the digitization of military history collections and the application of artificial intelligence (AI) in virtual museums over the past two decades.

In the section *Social media for digital humanities and community engagement*, British researcher Claire Ross analyzes the role of social media in digital humanities practices, showing how online platforms facilitate communication between researchers, museums, and the public. The author emphasizes that social networks allow broad audiences to be involved in scientific and cultural projects, facilitate the exchange of data and experience between participants, and create interactive educational scenarios that increase the effectiveness of digital humanities initiatives and strengthen the connection between the community and cultural heritage¹.

German-Iraqi researcher Nora Al-Badri specializes in digital art, decolonization of cultural heritage, and the application of technologies, particularly artificial intelligence, in museum practices². She emphasizes that the use of AI and digital technologies not only improves access to collections but also promotes active user engagement by creating interactive and educational experiences³.

In his article, Brazilian author Gabriel Menotti analyzes how generative artificial intelligence can influence the preservation and interpretation of cultural heritage, emphasizing the risks of cultural extraction and simplification of historical narratives. The author shows how AI can reproduce lost or damaged artifacts, create personalized narratives for users, and provide interactive access to collections, while analyzing the ethical and legal aspects of such technologies⁴.

Jing Miao, John McHugh, Thomas A. Carmichael – researchers from China and the US who study the use of generative AI-based chatbots in art museums, particularly for personalizing educational and interactive scenarios⁵. İhsan Suiçmez, Fikret Altınay, Gökhan Dağlı, Huan Zeng, Rustam Shadiev, Dilek İşlek, İpek Danju, Zafer Altınay –

¹ C. Ross, *Social media for digital humanities and community engagement*, [in:] *Digital humanities in practice*, eds. C. Warwick, M. Terras, J. Nyhan, London 2012, pp. 23–46.

² M. Al-Badri, *Distorted history: AI's skewed visions of the ancient world*, <https://collections.reading.ac.uk/ure-museum/explore/online-exhibitions/distorted-history-ais-skewed-visions-of-the-ancient-world> (accessed: 9 XI 2025).

³ Ibidem.

⁴ G. Menotti, *Generative AI and the expropriation of cultural heritage*, <https://link.springer.com/article/10.1007/s00146-025-02290-1> (accessed: 9 XI 2025).

⁵ B. Thiel, J. Bernhardt, F. Gaia, L. French, E. Villaespesa, *Negotiation of dominant AI narratives in museum exhibitions*, <https://link.springer.com/article/10.1007/s00146-024-02140-6> (accessed: 9 XI 2025).

an international team of researchers working to improve the user experience in museums using AI, VR, and interactive technologies⁶.

The British Museum and the Louvre are widely implementing 3D scanning technologies and interactive online platforms to display medieval and ancient artifacts, including weapons and armor. Research shows that 3D scanning allows for the creation of high-quality digital copies of exhibits, preserving their accuracy and detail, which is especially important for the study of military-historical objects⁷.

The Smithsonian Institution pays considerable attention to the digital accessibility of its collections, using VR tours and databases with artifact metadata. This allows visitors to receive personalized information and interactively engage with exhibits, including weapons and armor located in the museum's military history sections⁸.

The Metropolitan Museum of Art (New York) is developing its Arms and Armor collections by integrating generative artificial intelligence to reconstruct damaged or lost exhibits and create personalized educational narratives. Thanks to AI, it is possible to simulate historical battles and reconstruct details of artifacts, which helps visitors immerse themselves more deeply in the military-historical context⁹.

An international team of researchers in the field of digital humanities and museum technologies – Barbara Thiel, Jürgen Bernhardt, Francesca Gaia, Lucy French, and Erika Villaespesa – are studying the integration of AI into museum exhibitions and narrative formation. In particular, they emphasize the importance of a critical approach to the use of AI in museum exhibitions to avoid distorting historical narratives and ensure the authenticity of cultural heritage representation¹⁰.

Overall, foreign studies demonstrate the potential of generative AI in digital military history collections, including: 3D scanning and VR technologies for creating virtual exhibitions and online experiments with objects; reconstruction of damaged artifacts using AI for historically accurate reproduction; personalized narratives and interactive scenarios for visitors that promote educational impact and user engagement; critical analysis of historical narratives, which helps to avoid bias and distortion in the digital presentation of military history objects. These approaches are confirmed by a number of foreign scientific works, which form the modern methodological basis for the application of generative AI in virtual museums and digital exhibitions.

⁶ İ. Suiçmez, F. Altınay, G. Dağlı, H. Zeng, R. Shadiev, D. İşlek, İ. Danju, Z. Altınay, *Artificial intelligence application for museum to experiential transformation of cultural heritage and learning*, „Smart Learning Environments” 2025, No. 12(45), DOI: 10.1186/s40561-025-00404-2.

⁷ G. Menotti, op. cit.; B. Thiel, J. Bernhardt, F. Gaia, L. French, E. Villaespesa, op. cit.

⁸ J. Miao, J. McHugh, T.A. Carmichael, *Experiencing art museum with a generative artificial intelligence chatbot*, [in:] *Proceedings of the ACM on Human-Computer Interaction*, 2024, 8(CSCW2), pp. 1–18, DOI: 10.1145/3706370.3731650.

⁹ İ. Suiçmez, F. Altınay, G. Dağlı, H. Zeng, R. Shadiev, D. İşlek, İ. Danju, Z. Altınay, op. cit.

¹⁰ B. Thiel, J. Bernhardt, F. Gaia, L. French, E. Villaespesa, op. cit.

Ukrainian historiography

In Ukraine, the digitization of military history collections and the creation of virtual museums are only beginning to develop actively. In recent years, individual studies on our chosen topic have begun to appear. First and foremost, the article by L. Kuznetsova and I. Kushnarev, *Virtual Museums of Ukraine as a Means of Preserving Historical Memory in Wartime*, deserves attention. According to the authors, this has become particularly relevant in the context of Russia's full-scale military invasion of Ukraine. They also analyze the possibilities and prospects of using artificial intelligence technologies to preserve cultural heritage, in particular in the processes of preservation, restoration, and analysis of cultural artifacts¹¹.

In his monograph *Digital Humanities: Problems and Prospects*, V. Sydorenko systematically outlined the main challenges and potential avenues for the development of digital humanities in Ukraine. Among the problems he identified were low metadata standardization, the lack of established repositories, and weak integration into global indexes. In the section on prospects, V. Sydorenko proposes the creation of a national platform for digital humanities¹².

Virtual collections are partially mentioned by Ivan Khoma, Nataliia Vovk, Roman Holoshchuk, and Svitlana Muravska in the article *Promoting the Ukrainian Education and Culture Center 'Oseredok' through the digitization of Ukrainian Studies archival collections in Canada*, where the authors examine key issues related to the digitization of Ukrainian Studies archival collections located outside Ukraine¹³.

Since 2023, Ukraine has been gradually implementing the project *Museum Digital Community. Work in Progress* has been gradually implemented in Ukraine, with the aim of digitizing seven museum collections in Ukraine, including military history exhibits, to ensure their preservation and open access, supported by the European Union under the House of Europe program¹⁴. Particular attention is paid to the creation of online platforms within the framework of this project. The project is designed not only to preserve material heritage, but also to promote the educational and patriotic upbringing of visitors¹⁵.

¹¹ L. Kuznetsova, I. Kushnarev, *Virtual museums of Ukraine as a means of preserving historical memory in wartime*, „Cultural Studies” 2024, No. 43, pp. 142–155, DOI: 10.31866/2410–1311.43.2024.303042 [in Ukrainian].

¹² V. Sydorenko, *Digital humanities: problems and prospects*, Kyiv 2020 [in Ukrainian].

¹³ I. Khoma, N. Vovk, R. Holoshchuk, S. Muravska, *Promoting the Ukrainian Education and Culture Centre 'Oseredok' through the digitization of Ukrainian studies archival collections in Canada*, SCIA 2023, November, pp. 299–311.

¹⁴ House of Europe (in Ukrainian), <https://houseofeurope.org.ua/> [in Ukrainian].

¹⁵ The project to digitize seven museum collections *Museum digital community. Work in progress*, has begun, <https://muzey-dokm.pp.ua/rozpochav-robotu-projekt-z-otsyfruvannya-7-muzejnyh-kolektsij-muzejnatsyfrova-spilnota-work-in-progress.html> [in Ukrainian].

The Lviv Historical Museum is actively developing digital initiatives. One of the most significant projects is the *Museum in 3D*, which is being implemented with the support of the European Union as part of the *House of Europe* program. This project involves the digitization of exhibits from various locations of the museum, including the Arsenal Museum, which operates as a branch of the Lviv Historical Museum. The museum's website provides an opportunity to virtually explore its exhibition, which includes examples of cold and firearms, military paraphernalia, and other artifacts from more than 30 countries around the world. The exhibition is organized chronologically and thematically, allowing visitors to trace the evolution of different types of weapons. Its purely military focus and unique collection of weapons and military equipment are unparalleled in Ukraine¹⁶.

During the current ukrainian-russian war, digital platforms and virtual exhibitions are becoming an important tool for fostering patriotism, national memory, and promoting history among young people.

Methodology

The study uses a comprehensive interdisciplinary approach that combines analysis of scientific sources, case studies of foreign and Ukrainian virtual museums, and a review of modern digitalization technologies and generative artificial intelligence. The first step was a systematic review of the literature on the development of digital museum platforms, the use of VR/AR technologies, and AI in virtual exhibitions. The theoretical foundations were formed by developments in the field of museum informatics, initiated by D. Bearman and J. Trant¹⁷, as well as contemporary research in digital humanities, in particular the works of V. Sydorenko¹⁸ and T. Yaroshenko¹⁹. Particular attention was paid to examples of military history collections in the British Museum, the Louvre, the Smithsonian Institution, the Metropolitan Museum of Art, as well as Ukrainian digital projects, such as the online resources of the National Military History Museum of Ukraine²⁰ and the Lviv Historical Museum (including its branch, the Arsenal Museum)²¹.

The second stage involved comparing methods of presenting military history exhibits (weapons, armor, artifacts) in a digital environment, with an emphasis on the use of generative AI for reconstruction and interactive image reproduction. For this purpose,

¹⁶ Lviv Historical Museum, <https://www.lhm.lviv.ua> [in Ukrainian].

¹⁷ D. Bearman, J. Trant, *When museum informatics meets the world wide web*, „Journal of the American Society for Information Science” 2001, No. 51(1), pp. 3–56.

¹⁸ V. Sydorenko, op. cit.

¹⁹ T. Yaroshenko, *Digital humanities: a new field of knowledge or “new wine in old wineskins”?* *Culture and art of the 21st century: a dialogue on contemporary humanities*, Kyiv 2023, pp. 168–208 [in Ukrainian].

²⁰ National Military History Museum of Ukraine, <https://nvimu.com.ua/> [in Ukrainian].

²¹ Lviv Historical Museum, <https://www.lhm.lviv.ua> [in Ukrainian].

content analysis of the Europeana and Google Arts & Culture digital platforms was used, which made it possible to trace the possibilities of personalizing narratives for users, increasing the level of interactivity, and engaging metadata. Certain methodological approaches were borrowed from the works of F. Cameron and H. Robinson²² and M. Ridge²³, which reveal the potential of digital cultural heritage and crowdsourcing in the humanities.

The third stage was the synthesis of the results obtained, with an emphasis on their relevance to the contemporary Ukrainian context, in particular the formation of historical memory and patriotic narratives among young people in the conditions of the 2022–2025 war. It was also important to take into account Ukrainian digital initiatives, such as the Ukraine War Archive, which integrate practices of documenting the war and preserving collective memory²⁴. This approach made it possible to combine theoretical models with empirical cases, providing a holistic view of the prospects for integrating AI into digital military history exhibitions.

Digitized military-historical collections in Europe and the USA: opportunities for rapid retrieval with AI

Over the past few decades, leading museums in Europe and the US have been actively digitizing their military history collections, making them available in the form of open digital collections. For example, the British Museum in London offers more than 4.5 million digitized objects, among which artifacts of ancient and medieval weapons, armor, and military symbols occupy a significant place. The Louvre in Paris has opened access to more than 480,000 digital records, including a collection of medieval weapons and items related to the Crusades.

At the European level, there is the Europeana initiative, which brings together more than 58 million digital objects from various museums, archives, and libraries in the EU, including significant collections of military maps, photographs, letters, and personal belongings of participants in the wars of the 20th century. In Germany, there is the Deutsche Digitale Bibliothek, where separate collections are dedicated to military history, including materials from World War I and German military museums..

At the same time, the volume of such funds is constantly growing, which complicates the search and processing of information. At this stage, systems based on generative and

²² F.R. Cameron, H. Robinson, *Digital knowledgescapes: cultural, theoretical, practical, and usage issues facing museum collection databases*, [in:] *Digital epoch. Theorizing digital cultural heritage: a critical discourse*, ed. F. Cameron, Cambridge (MA) 2007, pp. 165–191.

²³ M. Ridge, *From tagging to theorizing: deepening engagement with cultural heritage through crowdsourcing*, „The Museum Journal” 2013, No. 56(4), pp. 435–450.

²⁴ Ukraine War Archive, <https://ukrainewararchive.org/> [in Ukrainian].

semantic AI are of particular importance. Machine learning algorithms not only enable quick keyword searches, but also recognize images in historical photographs, establish connections between artifacts (for example, between different types of weapons from the same period), and create interactive narratives for users. The use of AI also provides personalized access: researchers can obtain a selection of materials based on the topic of their query (e.g., *Renaissance armor* or *American artillery during World War II*).

The Arms and Armor department of The Metropolitan Museum of Art (New York) deserves special attention, as it houses one of the world's most representative collections of military armor and weapons (over 14,000 items). The uniqueness of this collection (figure 1) lies in the combination of European medieval knightly armor (helms of various types, cuirasses, backpacks, elbow pads, etc.) with Japanese samurai swords and European examples of cold weapons (swords, axes, spears, halberds, maces, etc.), as well as shields and horse armor. The museum's online catalog contains high-quality images, scientific descriptions, and data on the origin of the exhibits, making it an indispensable tool for military historians, cultural historians, and restorers.

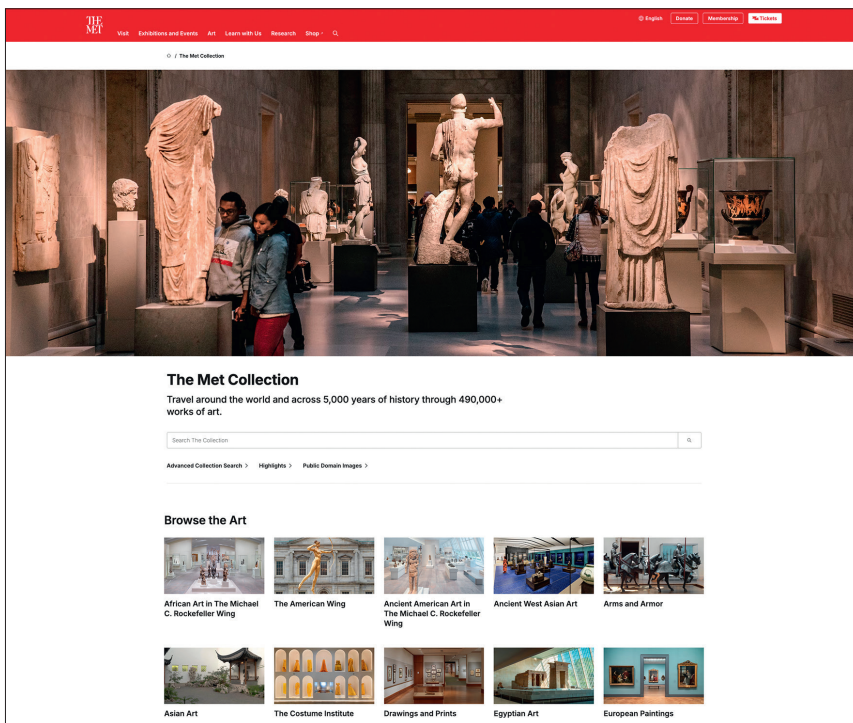


Figure 1. The Metropolitan Museum of Art online collection interface

Source: The Metropolitan Museum of Art, online collection interface, <https://www.metmuseum.org/art/collection> (accessed: 7 VI 2026).

The Imperial War Museums (IWM, UK) has one of the largest military history collections of the 20th and 21st centuries: approximately 11 million photographs (including official photo series from World War I and World War II, large collections of aerial photographs), over 155,000 three-dimensional objects (uniforms, insignia, weapons, equipment), and a total of over 33 million items of various types (figure 2). The digital catalog supports search and filters by object type, period, front, person, unit, etc.

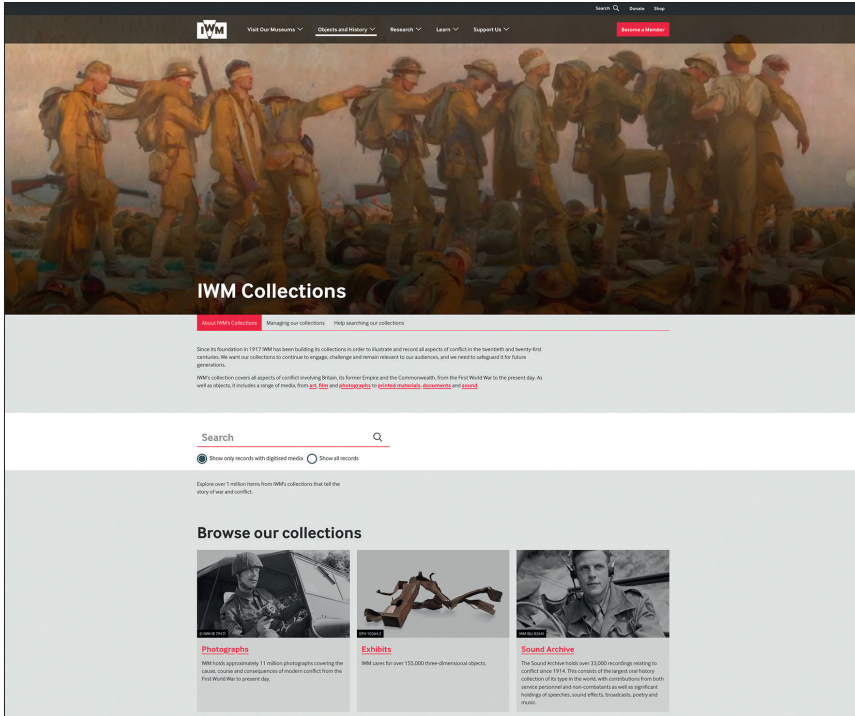


Figure 2. Imperial War Museums online collection interface

Source: Imperial War Museums, collections, <https://www.iwm.org.uk/collections> (accessed: 7 VI 2026).

An important part of the military history collections of the British Museum (London) consists of examples of ancient and medieval weapons: Assyrian and Persian helmets, Roman armor and gladiuses, medieval swords and crossbows, as well as early modern firearms. The museum pays particular attention to detailed metadata descriptions: each exhibit has attribution, information about materials, manufacturing techniques, history of use, and in many cases, scientific commentary. This level of cataloging facilitates comparative analysis and thematic searches, which is extremely valuable for weapons historians. The general online catalog (figure 3) covers many sections, including a selection of arms/armor – over 1,300 entries with detailed metadata and images (Assyrian helmets,

ancient armor, medieval and early modern weapons). The catalog has flexible filters and a guide to effective searching.

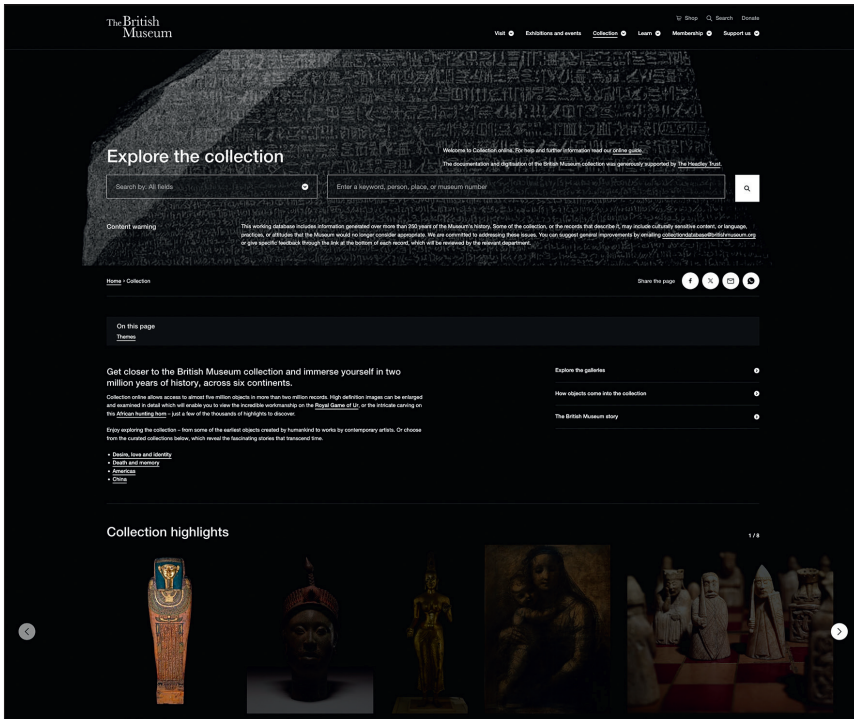


Figure 3. View the British Museum online catalog

Source: British Museum, online catalog, <https://www.britishmuseum.org/collection/> (accessed: 7 VI 2026).

The Musée du Louvre (Paris) offers a digital resource that is no less powerful in terms of volume, with a significant place given to materials related to the history of European wars in the Middle Ages and early modern times. Separate sections of the collections allow visitors to trace the symbolism of the Crusades, the development of knightly culture, and the evolution of military coats of arms and medals. The Louvre's distinctive feature is its close combination of military themes with art history: weapons and armor are often viewed not only as instruments of war, but also as works of artistic craftsmanship that reflect the stylistic trends of their era. The open database (figure 4) contains over 500,000 entries (updated daily) and is structured into the Arms & Armour section and related categories (medals, seals, books, engravings), allowing users to trace the evolution of military symbols, emblems, and weapon decoration in European schools.

In the American context, the Smithsonian Institution (National Museum of American History, Washington) plays a leading role, with a digital platform covering more than 3.2 million objects. It has extensive collections of US Army uniforms, firearms, military vehicles, as well as posters, photographs, and documents from World War I and World War II, flags, documents, and more. The Smithsonian Institution's general search interface (figure 5) provides access to over 17.9 million records, creating unique conditions for a comprehensive analysis of the material and visual culture of the US armed forces. The digital database also actively uses 3D models, which allow objects to be examined from different angles.

The National WWII Museum (New Orleans, USA) contains approximately 250,000 artifacts and archival materials; 9,000+ oral testimonies/interviews. The digital collections (figure 6) section has detailed categories by type of military branch (e.g., US Army – 13,666 interviews/records; USAAF – 5,555; US Navy – 3,954, etc.). This is one of the most comprehensive digital databases for researching personal narratives of World War II.

Military History Museum (Kyiv, Ukraine). The museum's collection contains over 250,000 items, including collections of cold steel and firearms from the 15th to 20th centuries, uniforms from various armies, military decorations, flags, and cartographic materials. A significant part of the archive consists of personal belongings of participants in the wars of the 20th century, correspondence, diaries, and frontline photographs. As part of the digitization process, an online catalog (figure 7) has been created with over 20,000 entries, systematized by type of weapon, branch of the military, and period (in particular, World War II, the war in Afghanistan, and the Russian-Ukrainian war of 2014–2025). An important component is the oral history database, which contains hundreds of interviews with veterans and combatants. The digitized materials are actively used for educational and scientific purposes and are also integrated into virtual exhibitions dedicated to key events in Ukraine's military history.

Lviv Historical Museum (LHM). One of the oldest museums in Ukraine, its collection includes over 380,000 exhibits, a significant part of which is a military-historical weapons collection. The digital database (figure 8) contains over 15,000 digitized examples of weapons and armor from the 14th to 19th centuries, including unique examples of European and Eastern weaponry (swords, sabers, arquebuses, cannons, and knight and samurai armor). A separate section is devoted to Ukrainian military formations of the liberation struggle period (1917–1921), as well as materials related to the activities of the Ukrainian Insurgent Army (UPA). The LHM digital catalog provides advanced search functions by weapon type, geographical origin, and date of manufacture. This allows researchers to quickly identify exhibits and compare them with the collections of other European museums.

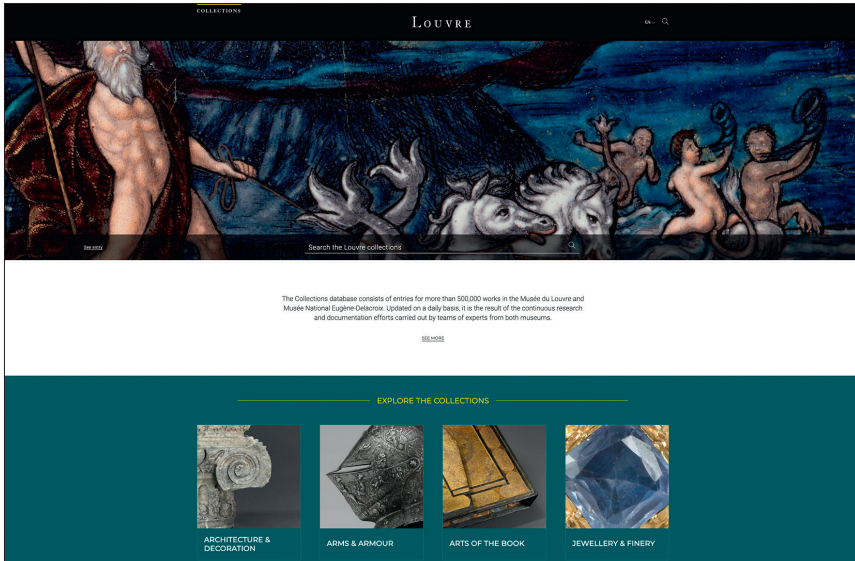


Figure 4. View the Musée du Louvre online catalog

Source: The Musée du Louvre, online catalog, <https://collections.louvre.fr/en/> (accessed: 7 VI 2026).

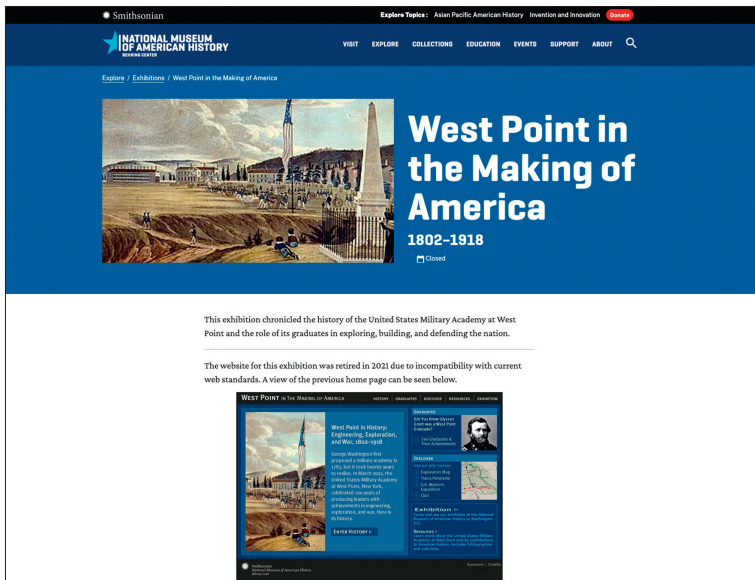


Figure 5. Smithsonian – West Point exhibition page

Source: Smithsonian – West Point exhibition page, <https://americanhistory.si.edu/explore/exhibitions/west-point-making-america> (accessed: 7 VI 2026).

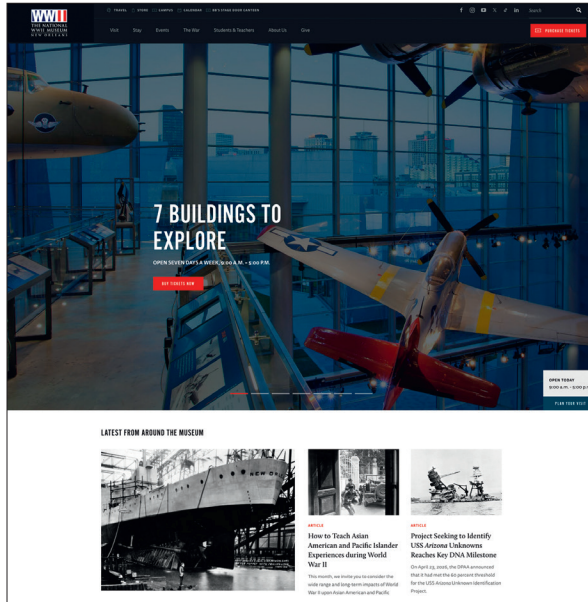


Figure 6. Home page of digital collections The National WWII Museum

Source: The National WWII Museum, <https://www.nationalww2museum.org/> (accessed: 7 VI 2026).

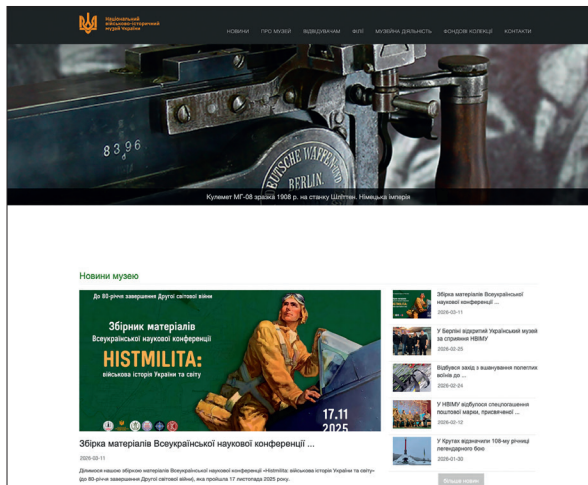


Figure 7. Home page of the digital collections of the Military History Museum in Kyiv

Source: National Military History Museum of Ukraine, <https://nvimu.com.ua/> (accessed: 7 VI 2026).

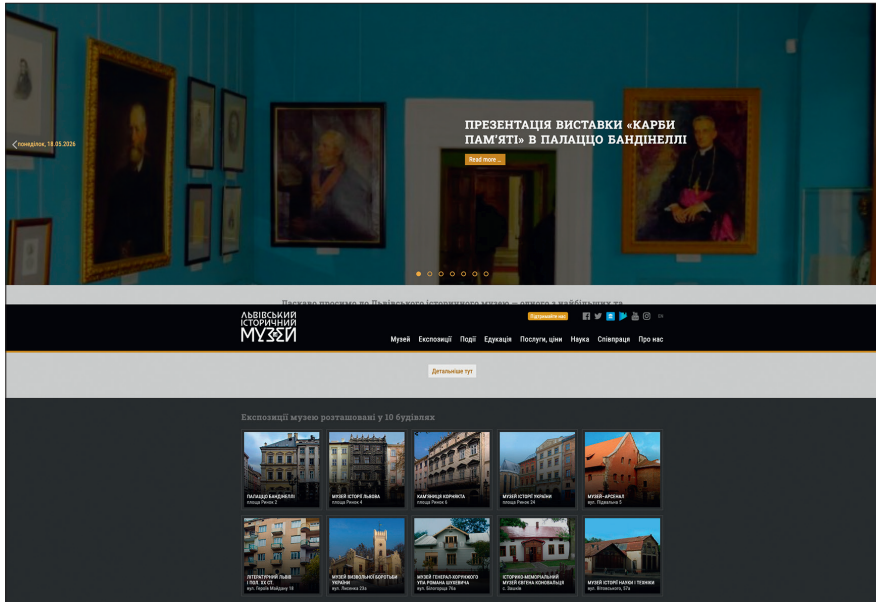


Figure 8. Home page of the digital collections of the Lviv Historical Museum

Source: Lviv Historical Museum, <https://www.lhm.lviv.ua> (accessed: 7 VI 2026).

The table 1 summarizes major digitized military-historical collections in leading museums and archives in Europe, the USA, and Ukraine. It highlights the scale of holdings, thematic focus, and the level of digital accessibility of their collections.

Table 1. Frequency of special characters

Museum/institution	Total holdings	Military-historical collections	Digitalization & online access	Special features
British Museum (London)	8+ million objects (4.5M digitized)	Arms & armour: ~1,300 items (Assyrian helmets, Greek/Roman armour, medieval swords, early firearms)	Online catalog with images, metadata, filters	Strong ancient & medieval coverage; good cross-cultural comparisons
Louvre (Paris)	~500,000 objects online	Arms & armour section incl. medieval & Crusader-era weapons, heraldic items	Daily updated database; high-resolution photos; metadata	Integration with broader medieval art collections
Metropolitan Museum of Art (New York), Arms and Armor	~1.5M total; ~14,000 arms & armour	European armour XV–XVII c., Japanese samurai swords & armour, horse armour, firearms	Extensive online catalog with detailed descriptions and photos	One of world's leading arms & armour collections
Smithsonian Institution (USA)	3.2M objects; 17.9M records searchable	Military uniforms, firearms, artillery, flags, WWII & WWI material	Centralized search portal; digitized photos and descriptions	Covers wide US military history; includes technology & equipment

Imperial War Museums (UK)	33M total; 11M photos; 155K 3D objects	Uniforms, insignia, weapons, vehicles, aircraft, WWI & WWII collections	Advanced search with filters (period, front, person, unit)	Massive photographic and oral history archive
The National WWII Museum (New Orleans)	~250,000 artifacts + 9,000 oral histories	Uniforms, weapons, documents, personal belongings, photos	Digital archive with thematic rubrics by branch (Army, Navy, USAAF)	Strong personal narratives; best WWII oral history base
Europeana (EU)	58M+ digital objects	Maps, photos, letters, military memorabilia (WWI & WWII focus)	Federated search across EU museums, archives, libraries	Pan-European integration; strong metadata standards
Deutsche Digitale Bibliothek (Germany)	Millions of digital items	Military history materials (WWI photos, documents, museum holdings)	Searchable digital catalog; multilingual metadata	National-level aggregation of German museums
Military-Historical Museum (Kyiv)	250,000 holdings; 20,000 digitized	Cold & firearms XV–XX c., uniforms, insignia, banners, personal belongings, letters, photos	Online catalog with thematic filters (weapons, branches, wars incl. Russo-Ukrainian war)	Strong oral history archive; virtual exhibitions
Lviv Historical Museum (Ukraine)	380,000 holdings; 15,000 digitized	Arms & armour XIV–XIX c. (European & Eastern), Cossack and UPA materials	Advanced search by type, origin, period	Unique Ukrainian military collections; comparative research potential
British Museum (London)	8+ million objects (4.5M digitized)	Arms & armour: ~1,300 items (Assyrian helmets, Greek/Roman armour, medieval swords, early firearms)	Online catalog with images, metadata, filters	Strong ancient & medieval coverage; good cross-cultural comparisons

Source: own development.

Integration of Ukrainian digital collections into international platforms

Over the past decade, Ukrainian museums, in particular the Military History Museum and the Lviv Historical Museum, have gradually been incorporating their digital collections into international cultural heritage aggregators. The most important area of cooperation is with Europeana, which already features thousands of Ukrainian military history objects, ranging from photographs and documents from World War I and World War II to weapons. Some collections are also integrated into the Digital Public Library of America (DPLA), which allows Ukrainian material to be brought into wider scientific circulation and made available to the global academic community. Thanks to the use of artificial intelligence and machine learning algorithms, these platforms provide fast multilingual search, automatic text recognition (OCR), visual identification of artifacts, and thematic clustering analysis. This opens up new perspectives not only for Ukrainian researchers, but also for foreign scholars, who can compare Ukrainian materials with the collections of the British Museum, the Smithsonian Institution, or the Metropolitan Museum of Art.

The integration of Ukrainian digital collections into international platforms requires not only organizational but also technical unification. An important step in this direction

is the use of international data models and metadata standards. Most European projects are dominated by the Dublin Core, CIDOC CRM, and LIDO formats, while Ukrainian museums often work with local description structures formed in Excel tables or small Access databases. This requires data mapping at the Europeana Data Model level, which ensures further compatibility with other resources.

The technological infrastructure for integration is based on the use of open protocols and services. OAI-PMH and Europeana API are used for data exchange, enabling automatic export and import of records. Museum object repositories are usually built on PostgreSQL or MySQL, using Drupal, Omeka S, or DSpace platforms. IIIF (International Image Interoperability Framework) is used for unified image representation, ensuring high quality and scalability of digital copies.

Artificial intelligence algorithms play a significant role in modern digital humanities. In particular, OCR and NLP provide automatic text recognition in military documents, while computer vision methods allow the identification of artifact categories, such as types of weapons or equipment. Semantic analysis and clustering algorithms are used to identify relationships between objects and group them according to chronological or functional characteristics. Additional possibilities are created by 3D modeling based on photogrammetry and generative neural networks, which facilitates the reconstruction of lost objects and the creation of virtual exhibitions.

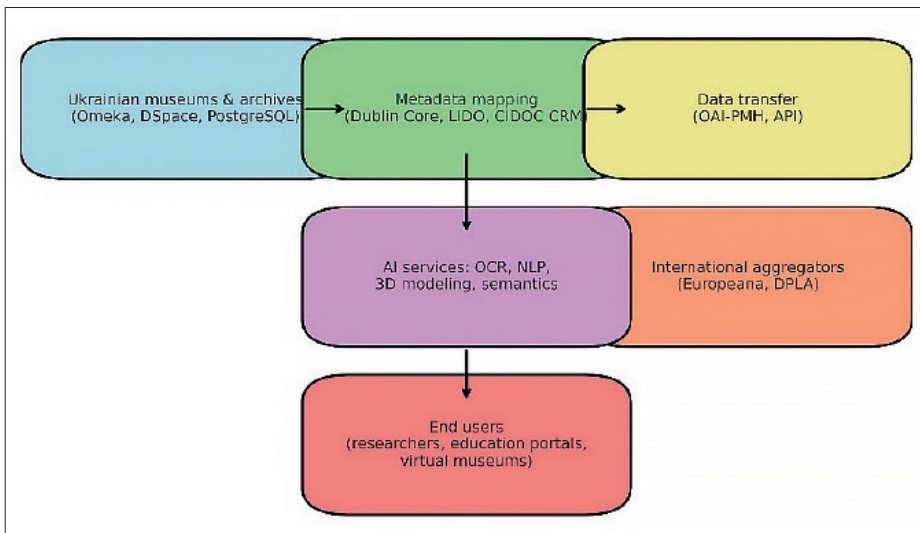


Figure 9. Model of integration of Ukrainian digital collections into international platforms

Source: own development.

How AI speeds up searching and working with funds

Semantic (vector) search and multimodal identification. Even when terminology varies between museums (“sallet”, “шолом-салет”, “helmet, sallet type”), semantic search models (e.g., based on vector indexes) allow related objects to be found by content rather than just by exact words. For images, visual feature recognition (blade type, armor profile, helmet shape) is used, which is especially useful in collections such as the IWM (millions of photos) or the British Museum (thousands of weapons/armor items)

Automatic metadata enrichment and OCR/ASR. Text recognition (OCR) on photo captions, staff charts, item cards, and newspapers allows you to quickly extract unit names, battle locations, dates, and serial numbers. For oral histories (WWII Museum), speech recognition (ASR) systems create full-text transcripts, which are then processed by LLM models to identify individuals, events, place names, and construct timelines.

Cross-collection navigation. Since the Smithsonian has tens of millions of records available through a single search center, and the Louvre has half a million+ public items, LLM agents can build “federated” queries (in a single human-readable formulation) and return grouped results: from a specific uniform sample to related documents, posters, and photos from different institutions.

Geospatial and comparative analysis. Combining metadata (date/location/unit) with cartographic layers allows us to reconstruct the routes of military units and correlate them with IWM photos (aerial photography, field photographs), objects from the Met/Louvre (weapon typology), and Smithsonian documents (orders, diaries).

Search scenario examples

The development of digital humanities involves not only the creation of large arrays of digitized data, but also the development of tools that ensure their real accessibility and effective use. Search scenarios are a central component of this process – structured models of user interaction with the system that allow relevant objects to be found in digital collections.

Modern digital collections use multi-level search mechanisms, combining traditional library cataloging practices with the latest technologies in artificial intelligence, semantic analysis, and multimodal search. This makes it possible to implement search scenarios of varying levels of complexity (figure 10):

1. *Basic keyword search.* The user enters a simple text query, and the system searches for matches in the names, descriptions, and tags of objects. This scenario is the most intuitive for a wide audience, including students and amateur local historians

2. *Faceted (multi-parameter) search*. Results are refined using filters that take into account the date of creation of the artifact, geographical origin, author, custodian institution, material of manufacture, etc. For example, the query “manuscripts” can be narrowed down to “Latin manuscripts of the 14th century from the Lviv collection”.
3. *Semantic search*. Thanks to the use of ontologies (CIDOC CRM, Dublin Core), users receive not only direct matches, but also objects linked by specific events, people, or places. This allows hidden contexts to be revealed – for example, finding artifacts related to a single historical figure, even if they are described in different languages and with different details in the metadata.
4. *Multilingual search*. Automatic translation and term normalization technologies enable simultaneous searches in multiple languages. The user enters a query in Ukrainian, and the system recodes it into English, German, or Polish and performs a global search. This is particularly relevant for the integration of Ukrainian collections into European aggregators such as Europeana.
5. *Visual similarity search*. Computer vision systems allow you to upload an image and receive similar objects in terms of style, ornamentation, color scheme, or shape. For example, a user can find other artifacts with Trypillian ornamentation without even knowing the correct term.
6. *Extended scenario “from query to research”*. In this case, searching becomes part of the scientific process: the user forms complex combined queries, creates thematic collections, exports metadata to external analysis tools (e.g., Gephi, Voyant Tools), and thus conducts digital research on cultural heritage.

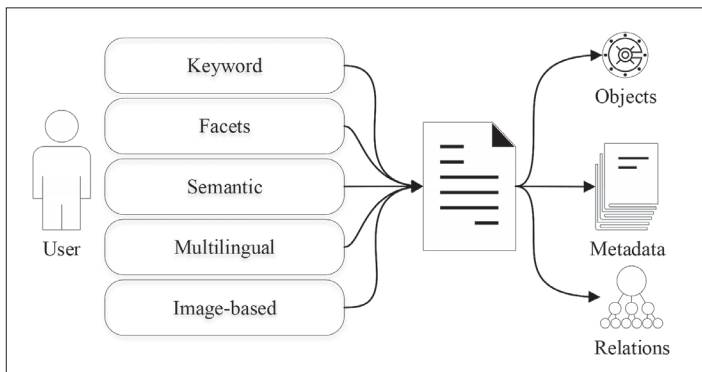


Figure 10. Search scenarios in integrated digital collections

Source: own development.

Thus, search scenarios are not only a technical tool, but also a key means of discovering new knowledge. They ensure the accessibility of Ukrainian cultural heritage to the

global community, increase the possibilities for its scientific study, and create conditions for innovation in the field of digital research.

Query Quality Score

An important aspect of search efficiency in integrated digital collections is determining the quality of the query formed by the user. To this end, we propose the Query Quality Score (QQS) metric, which takes into account a number of parameters related to the accuracy, relevance, and multilingualism of search results.

Formal definition

The quality of a search query can be expressed as a generalized formula:

$$QQS = \alpha * P + \beta * R + \gamma * C + \delta * M$$

where:

P – Precision – the proportion of relevant results among all found results;

R – Recall – the proportion of relevant results found among all possible results;

C – Clarity (of request)– the coefficient of formalization and clarity of keywords (for example, the use of a controlled vocabulary, ontologies);

M – Multilinguality factor – the coefficient of correctness of multilingual search (how well the system processes queries in different languages);

$\alpha, \beta, \gamma, \delta$ – weighting coefficients reflecting the priority of parameters (determined depending on the research objectives or platform).

Calculation example

Suppose a user entered the query *Ukrainian Insurgent Army documents*. Search results:

- 100 objects found;
- 85 of them are relevant (P=0,85);
- the collection contains a total of 120 relevant objects (R=85/120=0,71);
- the system applied a controlled vocabulary (C=0,9);
- multilingual support allowed to correctly find matches in Ukrainian and English (M=0,95).

With weight coefficients $\alpha = 0,35, \beta = 0,35, \gamma = 0,15, \delta = 0,15$:

$$\begin{aligned} QQS &= 0.35 * 0.85 + 0.35 * 0.71 + 0.15 * 0.9 + 0.15 * 0.95 \\ QQS &= 0.2975 + 0.2485 + 0.135 + 0.1425 = 0.8235 \end{aligned}$$

Therefore, the quality of the request is 0,82 (82%), which is considered a high indicator.

Table 2. Frequency of special characters

Request	Precision (P)	Recall (R)	Clarity (C)	Multilinguality (M)	QQS
World War II propaganda posters	0,88	0,76	0,90	0,92	0,84
Ukrainian Insurgent Army documents	0,80	0,70	0,85	0,90	0,78
Medieval knight armor Kyiv collection	0,75	0,68	0,82	0,87	0,73
Maps of Cossack military campaigns	0,83	0,72	0,88	0,89	0,80
Cold War intelligence archives	0,78	0,66	0,84	0,91	0,75

The calculation was made using the same formula with coefficients $\alpha = 0.35$, $\beta = 0.35$, $\gamma = 0.15$, $\delta = 0.15$.

Source: own development.

Explanation of the table results:

- World War II propaganda posters – the query is well formalized (the period and type of material are specified). Thanks to the use of controlled terms (e.g., propaganda posters), Clarity (0.90) is high. Multilingualism is also ensured, as the term “propaganda” has exact equivalents in most European languages.
- Ukrainian Insurgent Army documents – a complex query that can have different spellings (UPA, Insurgent Army, Українська повстанська армія). This reduces Precision and Recall due to discrepancies in cataloging.
- Medieval knight armor Kyiv collection – an example of searching for material objects. Precision is lower due to the variability of names (armor/armour, knight gear). Recall is also limited, as not all exhibits are cataloged with such details.
- Maps of Cossack military campaigns – a fairly clear query, but Recall is average, as not all maps have been digitized. Clarity is high, as the concepts of maps and military campaigns are formalized in ontologies..
- Cold War intelligence archives – an example of a more contemporary topic, where materials may be classified as restricted, which reduces Recall. Precision remains relatively high because the documents are clearly catalogued by topic.

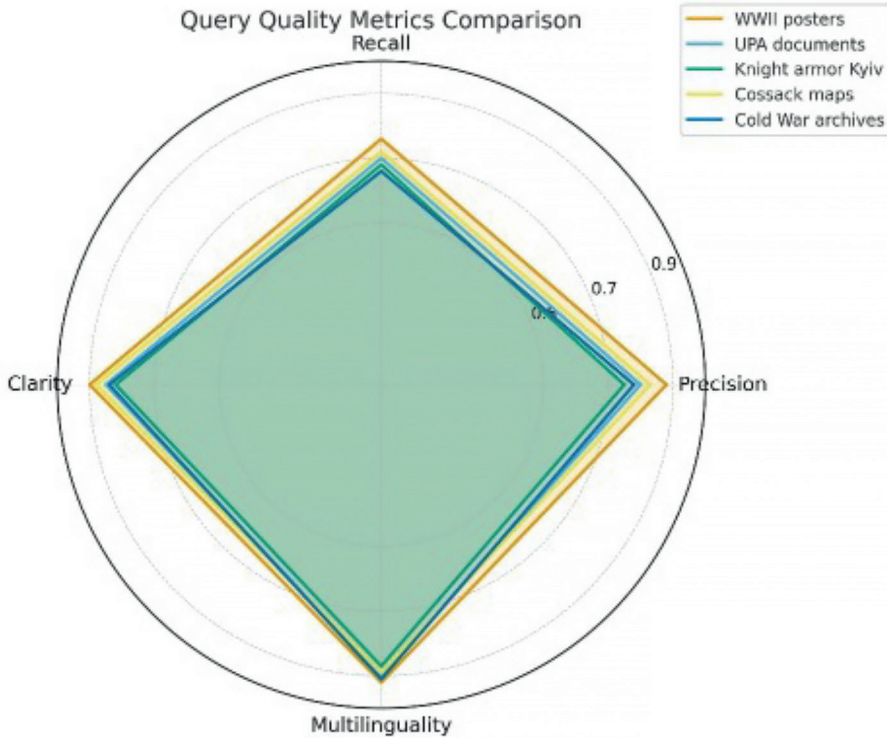


Figure 11. Search scenarios in integrated digital collections

Source: own development.

Figure 11 shows a comparison of the quality of search queries in digital collections according to four parameters: precision, recall, clarity, and multilinguality. The diagram reflects different levels of effectiveness for five thematic scenarios (World War II posters, UPA documents, knight armor from the Kyiv collection, maps of Cossack campaigns, Cold War archives), which clearly shows the dependence of search effectiveness on the formalization of terms and data availability.

Summary and conclusion

The study showed that the integration of Ukrainian military-historical digital collections into international digital platforms is a multidimensional process that combines technical, methodological, and humanitarian components. One of the key findings was the justification for the use of open interoperability standards (OAI-PMH, IIIF, RDF), which ensure unhindered data exchange and long-term compatibility of Ukrainian re-

sources with global digital heritage infrastructures. This avoids the fragmentation of cultural collections and creates the basis for a unified research space.

Another important achievement was the modeling of technical integration processes, visualized in the proposed scheme. It demonstrates how, at the level of APIs, metadata, and protocols, local Ukrainian initiatives can be merged with global systems such as Europeana or DPLA. This model not only reflects the technical architecture, but also outlines new opportunities for analytics and data enrichment using generative artificial intelligence.

The article also developed the concept of Query Quality Score (QQS) as an indicator of search query effectiveness. This approach has both theoretical and practical significance: it allows for quantitative assessment of search relevance, accuracy of results, and their representativeness. Practical examples of search scenarios have demonstrated that the use of QQS makes it possible to optimize research work, improve learning tools, and facilitate access to specialized content for users of different skill levels.

Special attention is paid to the potential of generative artificial intelligence in the digital representation of military history collections. In particular, it has been proven that it is capable of performing functions such as automatic metadata enrichment, creating new forms of data interpretation, building interactive narratives, and even reconstructing historical context. This not only broadens the horizons of digital humanities, but also shapes a new dimension of cultural diplomacy, as Ukrainian digital collections become accessible and understandable to the international community.

Thus, the results of the study emphasize the need for a systematic approach to the development of digital humanities resources in Ukraine. This involves not only technical modernization, but also the strategic combination of technologies, methodologies, and sociocultural practices. Further development in this direction should be based on expanding international partnerships, supporting open science, and investing in digital infrastructure. In the long term, this will create a competitive environment in which Ukrainian military history collections will become full-fledged nodes of the global digital ecosystem rather than peripheral elements.

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The potential of generative artificial intelligence in the digital representation of military history collections

Summary: The article examines the use of generative artificial intelligence in the creation of virtual museums and digital exhibitions of military history collections. The authors review international and Ukrainian digital platforms, including the British Museum, Louvre, Smithsonian Institution, Metropolitan Museum of Art, and Ukrainian online resources. Particular attention is paid to the use of artificial intelligence in the reconstruction of artifacts, creation of 3D models, and the development of personalized educational narratives. The article emphasizes the role of digital exhibitions in shaping historical memory and fostering patriotism among young people between 2022 and 2025 in the context of the Ukrainian-Russian war. It also introduces the concept of the *Query Quality Score* (QQS) as an indicator of search query effectiveness. This approach has both theoretical and practical significance, enabling the quantitative assessment of search relevance, result accuracy and representativeness.

Keywords: virtual museum, digital exhibition, military history collections, generative artificial intelligence, historical memory, 3D reconstruction, Query Quality Score

Potenzial generativer Künstlicher Intelligenz bei der digitalen Darstellung militärhistorischer Sammlungen

Zusammenfassung: Der Artikel befasst sich mit dem Einsatz generativer künstlicher Intelligenz bei der Einrichtung virtueller Museen und digitaler Ausstellungen von Sammlungen aus dem Bereich der Militärgeschichte. Die Autoren geben einen Überblick über internationale und ukrainische digitale Plattformen, darunter das British Museum, den Louvre, das Smithsonian, das Metropolitan Museum of Art sowie ukrainische Online-Ressourcen. Besonderes Augenmerk wird auf den Einsatz künstlicher Intelligenz zur Rekonstruktion von Artefakten, zur Erstellung von 3D-Modellen sowie zur Gestaltung personalisierter Bildungsnarrative gelegt. Der Artikel unterstreicht die Rolle digitaler Ausstellungen bei der Gestaltung des historischen Gedächtnisses und des Patriotismus unter jungen Menschen im Kontext des ukrainisch-russischen Krieges in den Jahren 2022–2025. In dem Artikel wurde zudem das Konzept des *Query Quality Score* (QQS) als Indikator für die Effektivität von Suchanfragen entwickelt. Dieser Ansatz ist sowohl von theoretischer als auch von praktischer Bedeutung: Er ermöglicht eine quantitative Bewertung der Suchtreffsicherheit, der Genauigkeit der Ergebnisse und ihrer Repräsentativität.

Schlüsselwörter: virtuelles Museum, digitale Ausstellung, militärhistorische Sammlungen, generative künstliche Intelligenz, historisches Gedächtnis, 3D-Rekonstruktion, Query Quality Score

Potencjał generatywnej sztucznej inteligencji w tworzeniu wirtualnych zbiorów militarno-histerycznych

Streszczenie: Artykuł poświęcony jest wykorzystaniu generatywnej sztucznej inteligencji w tworzeniu wirtualnych muzeów i cyfrowych wystaw kolekcji z zakresu historii wojskowości. Autorzy dokonują przeglądu międzynarodowych i ukraińskich platform cyfrowych, w tym British Museum, Luwru, Smithsonian, Metropolitan Museum of Art oraz ukraińskich zasobów internetowych. Szczególną uwagę poświęcono wykorzystaniu sztucznej inteligencji do rekonstrukcji artefaktów, tworzenia modeli 3D oraz kształtowania spersonalizowanych narracji edukacyjnych. W artykule podkreślono rolę wystaw cyfrowych w kształtowaniu pamięci historycznej i patriotyzmu wśród młodych ludzi w kontekście wojny ukraińsko-rosyjskiej w latach 2022–2025. W artykule opracowano również koncepcję *Query Quality Score* (QQS) jako wskaźnika skuteczności zapytań wyszukiwania. Podejście to ma znaczenie zarówno teoretyczne, jak i praktyczne, gdyż pozwala na ilościową ocenę trafności wyszukiwania, dokładności wyników i ich reprezentatywności.

Słowa kluczowe: muzeum wirtualne, wystawa cyfrowa, zbiory historii wojskowości, generatywna sztuczna inteligencja, pamięć historyczna, rekonstrukcja 3D, Query Quality Score