AN IMPLEMENTATION METHOD OF *GACA*: GLOBAL ART COLLECTION ARCHIVE

YOSUKE TSUCHIYA,[1,2] NAOKI ISHIBASHI[1]

[1] Musashino University, Graduate School of Data Science, Tokyo, Japan
g2251002@stu.musashino-u.ac.jp, n-ishi@musashino-u.ac.jp
[2] IT System Group, Ishibashi Foundation, Tokyo, Japan
g2251002@stu.musashino-u.ac.jp

In this paper, an implementation method of GACA, Global Art Collection Archive, is proposed. Each museum maintains their own archives of art collections. GACA dynamically integrate those collection data of artworks in each museum archive and provide them with REST API. GACA works as a integrated data platform for various kinds of viewing environment of artworks such as virtual reality, physical exhibitions, smartphone applications and so on. It allows users not only to view artworks, but also to experience the creativity of artworks through seeing, feeling, and knowing them, inspiring a new era of creation.

Keywords:
GACA,
museum database,
open data,
multidatabase system,
Art Sensorium Project

University of Maribor Press

DOI https://doi.org/10.18690/um.feri.5.2023.7
ISBN 978-961-286-745-4

1 Introduction

In recent years, many museums put large efforts to establish digital archives of their art collections. Some museums such as the Metropolitan Museum of Art in New York[1], the Paris Musées[2], and the Louvre Museum[3], provide their archives on art collections as open data. These archives contain various types of information (such as information about the collections and exhibitions) in various media formats (such as text, images, video, audio, and 3D models). The archives of these museums consist of different media and different genres of artworks, and multidatabase system approach [4,5,6,7] that seems applicable to integrate such heterogeneous archives. *Artizon Cloud* [8] is a multidatabase system that integrates various archives of art collection data and enables them to use inside the museum and public areas while properly handling issues such as copyrights.

By integrating collection data, new types of art experience could be implemented in both physical and virtual spaces. Art Sensorium Project[9], as shown in Figure 1, was launched in Musashino University with focusing on two key technologies as follows: 1) a multidatabase system architecture to integrate multiple art collections, 2) virtual space design and implementation for the Data Sensorium[10]. In particular, personalized art exhibitions where artworks are selected from a museum archive and displayed based on the viewer's tastes and viewing tendencies could be implemented [11].

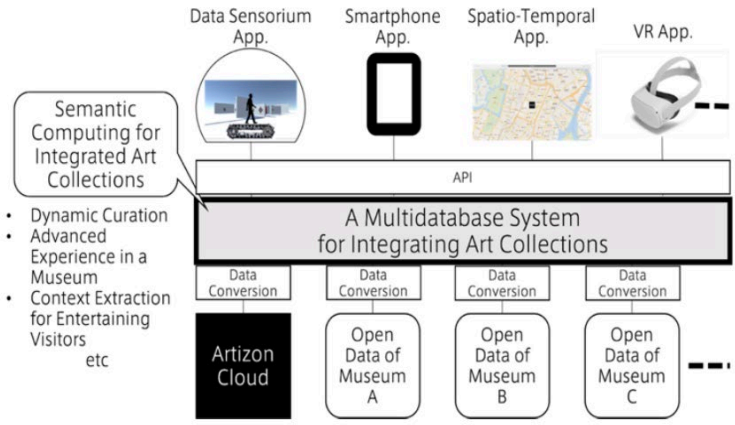

Figure 1: A System Architecture of Art Sensorium Project

Source: own.

The primary focus of the Art Sensorium Project is the design and implementation of a multidatabase system that integrates art collections. Therefore, in this paper, an implementation method of *GACA*, Global Art Collection Archive, is proposed. Each museum creates its own archives of art collections, then GACA integrates these archives and provides appropriate data for use in virtual reality, Data Sensorium, personal fabrication[12], and other applications. The structure of the paper is as follows: Section 2 reviews related researches and highlights the challenges that need to be addressed. Section 3 outlines the GACA architecture, designed to integrate with an arbitrary number of museum archives. Section 4 details the implementation of GACA, focusing on its integration with three specific museum archives. Section 5 presents two experiments conducted to verify the system's functionality and effectiveness.

2 Related Researches

There are several existing integrated archives of art collections, including Japan Search[13] and the Heritage Connector[14] in the UK. These archives receive government subsidies and contain art collections from museums within their respective countries. Google Arts & Culture [15] is another example of an integrated archive. It provides art collections and connects them to other web services provided by Google such as Geo Locations and Augmented Reality. These existing integrated archives of art collections have issues in terms of data heterogeneity and collection coverage.

The first issue is data heterogeneity, which can manifest in two ways: the heterogeneity of the data structure and the heterogeneity of the data notation. In terms of data structure, art collection data of each museum are typically organized according to each own rules. This results in missing data items (e.g., an item that exists in one museum but not in another) and non-uniform data types (e.g., a serial ID of a work may be an integer in one museum but a string in another).

The other is about the heterogeneity of data notation, such as the language notation of the artist's name, unit of artwork size, and so on. For example, the same "artist name" may be listed in multiple languages in one museum, while in another museum, only listed in the local language. Additionally, the size of a work may be listed in centimeters in one museum, but in inches in another.

The second issue is collection coverage. Covering art collections from all over the world is a challenging task. To achieve this, an environment should be created where art collection data from each museum can be easily shared online. Japan Search and the Heritage Connector are federally subsidized integrated collection archives that provide collection data from museum archives via API linkage or CSV. However, their coverage is limited to data from domestic museums.

Google Arts & Culture is a cloud service provided by Google. Museums can choose to manually register their collections with Google Arts & Culture, which can then be linked to other Google services such as Google Maps and AR. However, not all museums provide all of their collection data to Google Arts & Culture (although some, such as the MET, do provide API integration). Many museums register their collections with Google Arts & Culture for public relations purposes, such as showcasing famous painters. This means that less famous, but still significant and important artworks are not accessible.

Our goal is to create a viewing environment that allows users not only to see famous artworks, but also to experience the creativity of artworks through seeing, feeling, and knowing them, inspiring a new era of creation. To achieve this, GACA is designed as a data platform that integrates various archives of art collection data maintained by each museum, making them accessible through a range of devices and applications (as shown in Figure 2). To facilitate seamless integration and use of these data within the devices and applications, GACA will be implemented as a multidatabase system that addresses the previously mentioned issues of heterogeneity and collection coverage.

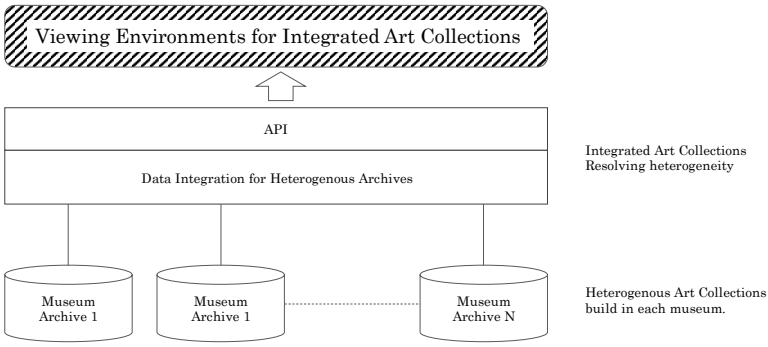

Figure 2: Idea of GACA
Source: own.

3 GACA Architecture

GACA is designed as shown in Figure 3 to address the issues with existing integrated archives, such as data heterogeneity and collection coverage. Specifically, GACA consists of five main components, Multidatabase Engine for Integrated Art Archive, Integrated Art Archive, Data Converters, Dictionary Connectors and Integrated API.

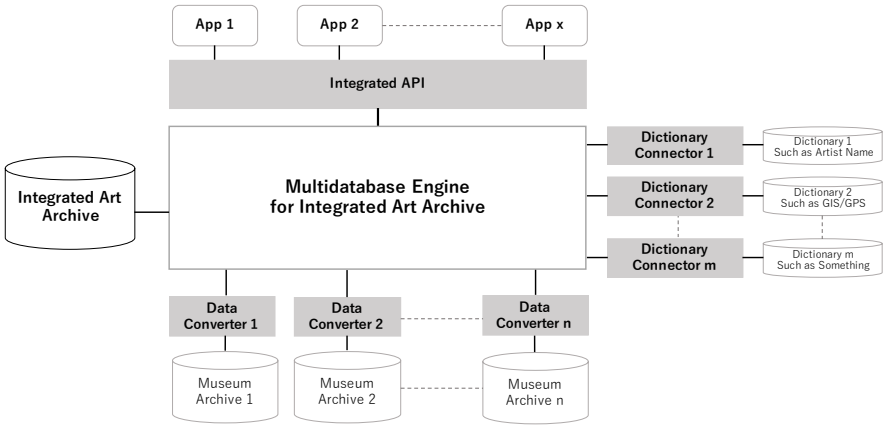

Figure 3: A System Architecture of GACA
Source: own.

3.1 Multidatabase Engine for Integrated Art Archive

The Multidatabase Engine for Integrated Art Archive serves as the core of GACA. It incorporates various curatorial functions of data from the Integrated Art Archive, utilizing methods such as image recognition, machine learning, spatial and temporal operations and so on. Multidatabase Engine sends requests based on those methods to the Integrated Art Archive, and receive integrated art collection data of each museum as response from the archive.

3.2 Integrated Art Archive

The Integrated Art Archive serves as a central location where art collection data from various museum archives are stored. As described below, Data Converters are used to store the art collection data of each museum with converting to a common

schema. Dictionary Connector adds a unique key to those art collection data to connect it to the dictionary. The Integrated Art Archive utilizes these unique keys to provide the integrated art collection data in response to requests from the Multidatabase Engine.

3.3 Data Converters

The Data Converters convert the data schema of the art collections in each museum archive into a common data schema. Each museum builds its own archive, so each museum has a different schema for its collection data. For example, in one museum archive, artwork and artist information are maintained in separate tables, and each assigned a unique ID. In contrast, another museum archive maintains artworks and artists on the same table but does not assign a unique ID to artists. Additionally, each museum retains different types of media data. For instance, regarding multimedia data in a collection, one museum may only have images, while another may also manage audio and video in addition to images.

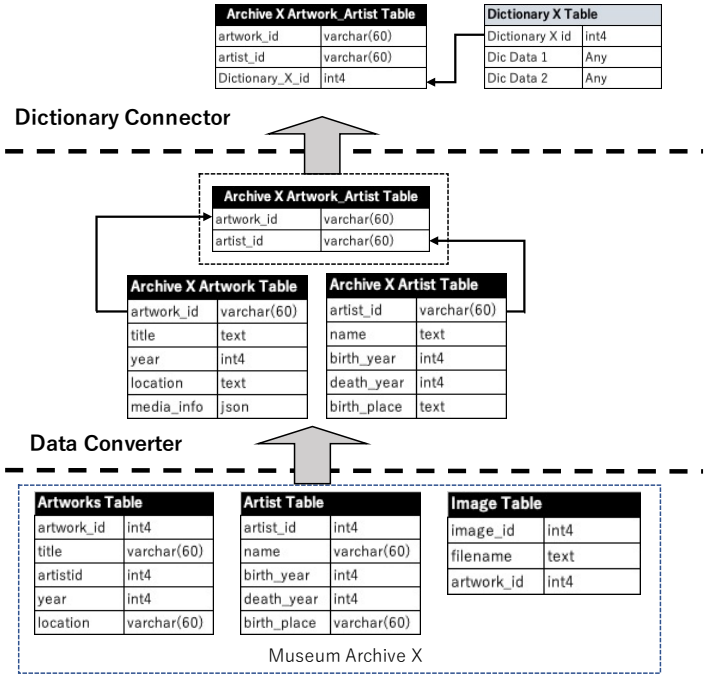

Figure 4: A Data Flow in GACA

Source: own.

To address this heterogeneity among museum archives, GACA converts the collection data schema of each archive into a common collection data schema and stores it in the GACA Integrated Archive, as shown in Figure 4. The Data Converters generate three tables for managing collection data: a table of artworks, a table of artists, and a table of correspondence between artworks and artists. This allows the collection data from each archive to be combined at the meta-level, providing a comprehensive overview of the collections in the GACA Integrated Archive.

3.4 Dictionary Connectors

Dictionary Connectors obtain information on references (dictionary information) and assign unique information for data retrieval in GACA. Collection data contains a variety of information. For example, artist information includes the artist's name, place of birth, date of birth, and date of death. Artwork information includes the name of the work, year of creation, place of creation, materials, techniques, and dimensions. While this information is useful for searching collections, the notation and units differ within each museum's archives. For example, names may be written in the native language of the museum, and the locations and units of measurement for dimensions of works may vary (e.g., inches or centimeters). These differences make it difficult to search and compare information across different museums' archives.

To address the issue of heterogeneity of data notation, the Dictionary Connector connects to relevant dictionary databases, including artist notations, dimensions, time, and location data. The Dictionary Connector also generates a unique key for the art collection data from the dictionary database. It assigns this unique key to the collection data of each archive, connecting to the dictionary data. This enables cross-search and information extraction within the GACA.

By implementing Dictionary Connector and Data Converter, GACA enables to integrate of each museum archive dynamically, without selecting and limiting the collection data. The museum archives which store huge amounts of collection data could also easily be integrated into GACA by implementing the data converter. As a result, the GACA addresses the issue of collection coverage.

3.5 Integrated API

Integrated API works as the interface between Multidatabase Engine for Integrated Art Archive and various types of application such as virtual museum, Data Sensorium and so on. Integrated API designed as RESTful API with implementing a token authentication. When the Integrated API receives a request with a search key via GET or POST, API send the search key to Multidatabase Engine and receive the matching collection data. Integrated API return the collection data to the application with formatted in a supported data format such as JSON, CSV, or XML.

4 An Implementation of GACA

A GACA prototype system was implemented as shown in Figure 5. It is connected to three museum archives: the MET Collection, the Paris Musées Collection, and the Artizon Cloud. These archives are independently implemented and some of them offer open data with REST API. In addition, GACA is connected to an artist dictionary on Wikidata[16], which includes notation of artist names in five different languages: English, French, Chinese, Korean, and Japanese. As a result, GACA has integrated approximately 800,000 art collections from the three archives and provided access to the collections via REST API with artist names in five different languages (English, French, Chinese, Korean and Japanese).

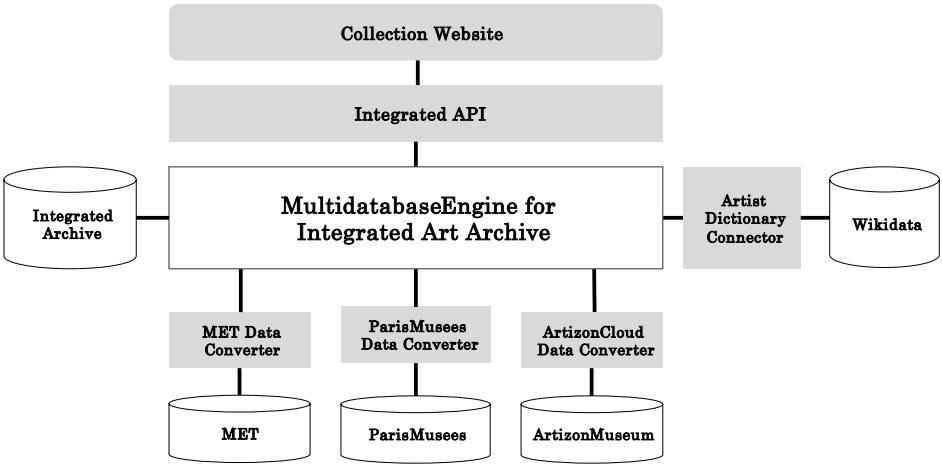

Figure 5: An Implementation of GACA

Source: own.

4.1 MET Data Converter

As shown in Figure 4, the role of data converters is to generate three tables with a common schema. The Metropolitan Museum of Art (MET) in New York City has approximately 480,000 artworks, documents, and other materials available as open data. This data can be accessed through REST API or CSV. However, the MET's collection data is organized into a single table with both artist information and artwork information. Each artwork is given a local unique ID (Object ID), but the artists do not have IDs. On the other hand, each artist information includes a Wikidata URL, which has an Entity ID that uniquely identifies the artist information in Wikidata. To convert this data structure, the Data Converter for the MET Collection follows these steps:

- Separate the data about the artwork and the artist from the collection CSV file.
- Create a table of artworks using Object ID of the artworks as a key.
- Extract Entity IDs from the Wikidata URLs of the artists.
- Create a table of artist data using the Entity ID extracted in step 3 as a key.
- Create a table of correspondence between the Entity ID of the artist and the Object ID of the artwork.

4.2 Paris Musées Data Converter

Paris Musées is a public organization that oversees 14 museums in the city and has made the collections of approximately 360,000 items housed in these institutions available as open data. The collection data is shared among the 14 museums and can be accessed via a JSON-formatted API. In contrast to the MET API, which is based on RESTful, a GraphQL query must be generated to retrieve the collection data from Paris Musées. Each artwork and artist in the collection has a unique ID, and the artwork is also associated with the ID of the museum that owns it. To convert this data structure, the Data Converter for Paris Musées follows these steps:

1. Submit a GraphQL query to obtain information on the 14 museums in the Paris Musées network and retrieve the data in JSON format.

2. Using the ID of each museum as a key, submit a GraphQL query to retrieve the collection data stored in each museum and obtain the data in JSON format.
3. Separate the data related to artworks and artists from the data obtained in step 2.
4. Create an artwork table using the unique ID of each artwork as the key.
5. Create an artist table using the unique ID of each artist as the key.
6. Create a table of correspondences between the unique ID of each artwork and the unique ID of each artist.

4.3 Artizon Cloud Data Converter

The Bridgestone Museum of Art, which was founded in 1952, was reopened in 2020 as the Artizon Museum[17]. Artizon Cloud is a multidatabase system that contains various data archives related to artworks owned by the Artizon Museum. These archives include basic information of collection, evidential documents, multimedia (including images and sound), text, and event archives. Artizon Cloud controls the scope of collection offerings through three layers (Private Zone, Museum Zone, Public Zone) and rights relations. The Artizon Cloud Data Converter converts the data structure of the collection data published in the Public Zone of Artizon Cloud using the following steps:

1. Separate the data about artworks and the data about artists from the Artizon Cloud art collection.
2. Create a table of artworks using the artwork IDs as keys.
3. Create a table of artists using the artist's ID as a key.
4. Create a table of correspondences between the artwork IDs and artist IDs.

4.4 Artist Dictionary Connector

In this prototype system, Wikidata was utilized as the reference dictionary for artist notation. Wikidata is a collaborative, open data database that is compiled and normalized by volunteers. It is freely available to the public and has gained a reputation for credibility, receiving the Open Data Publisher Award in 2014. Additionally, its open-source nature has made it a central hub for datasets from various institutions, including libraries and museums.

Figure 6 demonstrates the process of creating the artist notation dictionary data from Wikidata. The MET have already used Wikidata URLs as references for artist information in its collection data, and the MET Data Converter employs Wikidata Entity ID as the artist ID of MET. Thus, the Dictionary Connector first uses this Entity ID to obtain the notation of the relevant artist in five languages and create a basic dictionary table. It then searches the basic dictionary data table for the artist notations of Paris Musées and Artizon Cloud, querying Wikidata for any artist notations that do not match. These notations are obtained in the five languages and added to the basic dictionary table. Finally, the Dictionary Connector searches the respective Artwork-Artist tables generated by the Data Converter and assigns the corresponding artist a Wikidata Entity ID. This connects the artist information in each museum collection with the information in the notation dictionary, using the Wikidata Entity ID as the key.

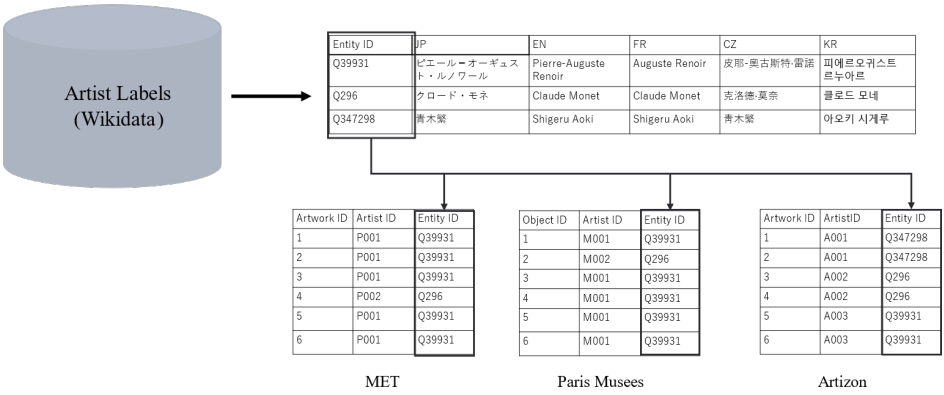

Figure 6: A Workflow of Dictionary Connector
Source: own.

4.5 Integrated Art Archive

Integrated Art Archive is implemented with a relational database management system (PostgreSQL version 12.3). As shown in Figure 3, art collection data, which is converted to a common data schema by Data Converter, are stored in artworks tables and artist tables. Also, Wikidata Entity ID of the artist's name is added to the artwork-artist table. Integrated Art Archive receives the query by SQL from Multidatabase Engine and returns the result set.

4.6 Multidatabase Engine for Integrated Art Archive

As a prototype of multidatabase engine for the Integrated Art Archive, a method to search art collections by the different languages of artist names was implemented. It works as following steps to retrieve the art collection data from Integrated Art Archive.

1. Receive all or a part of an artist's name from the Integrated API. The artist's name can be in any five languages (Japanese, English, French, Chinese, and Korean), obtained from the Dictionary Connector.
2. Search the received artist name in the Artist Dictionary to obtain the Wikidata Entity ID and notation of the artist name by five languages of the artist.
3. Submit a query to the Integrated Art Archive using the artist's Wikidata Entity ID obtained in step 2 as a key to retrieve the relevant artist's collection data. The query is submitted by SQL.
4. Receive the result set (integrated art collection data) from the Integrated Art Archive and return it to the Integrated API.

4.7 Integrated API

In this prototype, the Integrated API was implemented using Python 3.6.8 and the Flask framework for a web application. As shown in Figure 7, the API provide endpoints that accept requests by GET or POST methods and returns the corresponding data in JSON format. At this point, two endpoints have been implemented as follows: 1) an endpoint for artist name, which returns a set of Wikidata Entity ID and the artist's name in five languages from the Artist Dictionary, 2) an endpoint for Wikidata Entities ID, which returns a list of art collection data from the Multidatabase Engine for the Integrated Art Archive. To ensure security, the Integrated API was implemented with token authentication using JWT (JSON Web Token). Only authorized applications can access the Integrated API.

In addition to the API, the website provides a form for submitting keys to the endpoints and displays the results. The website allows searches of the integrated data collection by artist name and artwork name, as well as searches of the collection data for each individual museum.

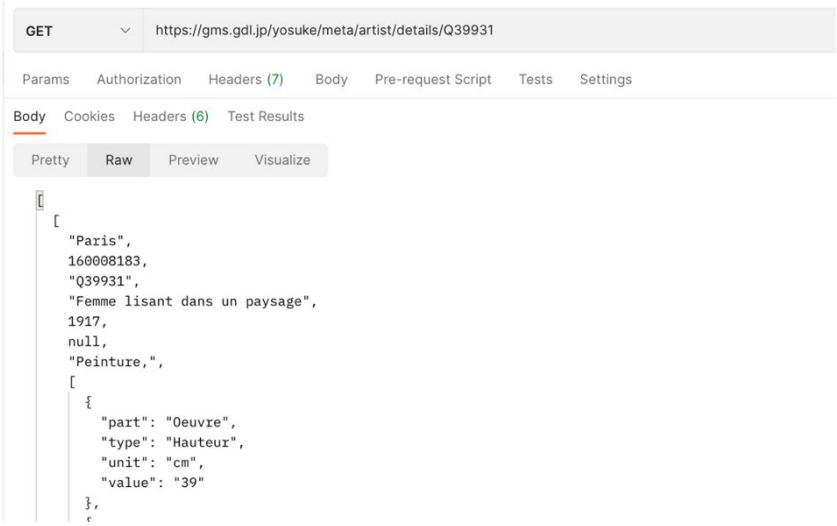

Figure 7: A Example of JSON Data returned from Integrated API
Source: own.

5 Experiments

To confirm that the system is functioning as intended, two experiments were conducted: one to test the integrated search capabilities of the collections, and the other to test the operation of the Integrated API.

5.1 Experiment of Integrated Collection Search

An experiment was conducted to test the integrated search functionality of the system. During the experiment, it was confirmed that the following two points were working as expected: 1) searches for artists could be performed in five languages, and 2) the results showed that the works of the corresponding artists were retrieved from all three archives and displayed in a single list. For example, "Renoir" by Pierre-Auguste Renoir (1841-1919) is rendered as "Renoir" in English and French, "雷諾瓦" in Chinese, "르누아르" in Korean, and "ルノワール" in Japanese. Searches for "Renoir" in each language all returned the expected results. Figure 8 shows the results of the artist search with each "Renoir" notation, demonstrating that Pierre-Auguste Renoir can be searched in each language. Figure 9 shows some of the

results, with works from the Metropolitan Museum of Art, Paris Musées, and Artizon Cloud displayed in the same list.

During the implementation of the system, several issues became apparent. One issue is that keys that are not registered in the dictionary database cannot be retrieved. In this case, the artist notation dictionary was created from Wikidata, but if the notation for the relevant artist in a particular language was not present in Wikidata, it would not appear in the search results. As shown in Figure 7, "ルノワール" in Japanese corresponds to both "Renoir" and "Lenoir" in English, resulting in the retrieval of Albert Lenoir (1801-1891) and Alfred Lenoir (1850-1920). However, the Chinese ("阿爾伯特-勒努瓦", "阿尔弗雷德-勒努瓦") and Korean ("알버트 르누아르", "알프레드 르누아르") notations for these two artists are not currently present in Wikidata, so they could not be registered in the dictionary when it was created. Therefore, searches for "勒努瓦" in Chinese or "알프레드" in Korean would not retrieve these two artists.

Artworks of Pierre-Auguste Renoir

Name: ピエール＝オーギュスト・ルノワール,Pierre-Auguste Renoir,Auguste Renoir,皮耶-奧古斯特·雷諾瓦,피에르오귀스트 르누아르
Birth; 1841 Death: 1919

API	Title	BeginYear	EndYear
Paris	Les deux baigneuses, gravure publiée dans l'album de clôture de "l'Estampe originale" - Neuvième livraison (janvier-mars 1895)	1895	
Paris	L'Enfant à la chaise (Jean Renoir)	1895	
met	Hills around the Bay of Moulin Huet, Guernsey	1883	1883
ATZ	花のついた帽子の女	1917	
Paris	Femme lisant dans un paysage	1917	
met	Young Girl with a Cat, after a portrait of Julie Manet by Renoir	1889	1889
Paris	Buste de Coco	1907	1908
met	Still Life with Peaches and Grapes	1881	1881
met	Nini in the Garden (Nini Lopez)	1876	1876
Paris	Femme assise	1900	1906
met	A Young Girl with Daisies	1889	1889
Paris	Les Enfants jouant à la balle	1893	
met	Eugène Murer (Hyacinthe-Eugène Meunier, 1841–1906)	1877	1877
met	Tilla Durieux (Ottilie Godeffroy, 1880–1971)	1914	1914
met	A Waitress at Duval"s Restaurant	1870	1880
met	Marguerite-Thérèse (Margot) Berard (1874–1956)	1879	1879
Paris	Tête d'enfant, lithographie publiée dans "l'Estampe originale" - Quatrième livraison (octobre-décembre 1893)	1893	
Paris	Maison à Cagnes	1910	
ATZ	カーニュのテラス	1905	
met	Bouquet of Chrysanthemums	1881	1881
met	A Road in Louveciennes	1865	1875
ATZ	すわる水浴の女	1914	

Figure 8. A Result of Artist Search in Different Language
Source: own.

Additionally, artworks by unknown artists also cannot be retrieved. The Metropolitan Museum of Art collection has approximately 15,000 works and the Paris Musées collection has 86,000 works with an unknown artist (works with an anonymous or unknown artist name). These works, such as those with blank or "Anonyme" in the artist's name, have not been retrieved by the artist search.

On the other hand, there is more information about artwork than just its artist name, such as the date of creation, location of the work, size, and more. There is also information derived from image analysis of the artwork. Connecting separate dictionaries corresponding to this information and using them to search the collection would be needed. Currently, there are 800,000 artworks subject to search, and connecting multiple dictionaries will be necessary to retrieve artworks that users are seeking from this large collection.

Result of ルノワール

META ID	日本語	英語	フランス語	中国語	韓国語
Q2831339	アルベール・ルノワール	Albert Lenoir	Albert Lenoir		
Q2834901	アルフレド＝シャルル・ルノワール	Alfred Lenoir	Alfred Lenoir		
Q39931	ピエール＝オーギュスト・ルノワール	Pierre-Auguste Renoir	Auguste Renoir	皮耶-奧古斯特·雷諾瓦	피에르오귀스트 르누아르
Q50713	ジャン・ルノワール	Jean Renoir	Jean Renoir	讓·雷諾阿	장 르누아르

Result of Renoir

META ID	日本語	英語	フランス語	中国語	韓国語
Q39931	ピエール＝オーギュスト・ルノワール	Pierre-Auguste Renoir	Auguste Renoir	皮耶-奧古斯特·雷諾瓦	피에르오귀스트 르누아르
Q50713	ジャン・ルノワール	Jean Renoir	Jean Renoir	讓·雷諾阿	장 르누아르

Result of 雷諾瓦

META ID	日本語	英語	フランス語	中国語	韓国語
Q39931	ピエール＝オーギュスト・ルノワール	Pierre-Auguste Renoir	Auguste Renoir	皮耶-奧古斯特·雷諾瓦	피에르오귀스트 르누아르

Result of 르누아르

META ID	日本語	英語	フランス語	中国語	韓国語
Q39931	ピエール＝オーギュスト・ルノワール	Pierre-Auguste Renoir	Auguste Renoir	皮耶-奧古斯特·雷諾瓦	피에르오귀스트 르누아르
Q50713	ジャン・ルノワール	Jean Renoir	Jean Renoir	讓·雷諾阿	장 르누아르

Figure 9: A Result of Integrated Search by Artist name

Source: own.

5.2 Experiments of Integrated API

As a test of the Integrated API, we created a simple artwork viewer in Python that displays images of artworks corresponding to the artist's search. This application displays images of the artist's artwork according to the following procedure:

1. When the application is launched, the user sends a username and password via POST to obtain an access token.
2. The user send the Entity ID of the artist in the form at the top of the application.
3. The application accesses the API based on the Entity ID entered and obtains the JSON data of the list of works.
4. The application extracts the image URL of the artwork from the JSON data.
5. The application accesses the image URL of the artwork extracted in step 4 and downloads it.
6. Once all images have been downloaded, the application displays them.

Figure 10 shows the artworks of Auguste Renoir displayed in the simple image viewer we created Note that the API only includes images that are in the public domain, and only the corresponding artworks are displayed on the viewer[1].

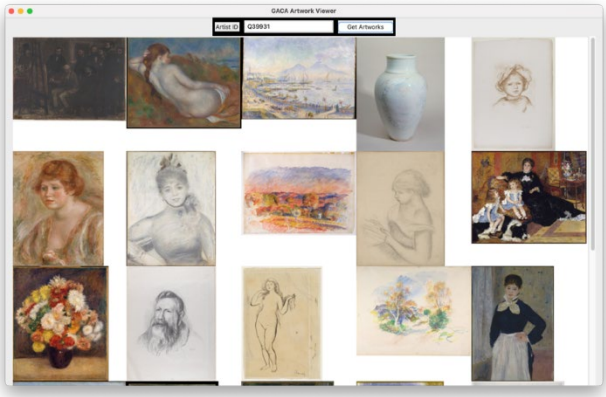

Figure 10: Artwork Viewer from Integrated API
Source: screenshot, own, 2023.

[1] Images are cited from Met Collection: https://www.metmuseum.org/art/the-collection, and Paris Musées Collection: https://www.parismuseescollections.paris.fr/en (2022).

One issue with the Integrated API is the time required to download images when the list of works returned from the API becomes large. GACA maintains the URL of images in each collection data, so they must be accessed and downloaded each time. Due to network or system problems at individual archives, it may delay downloading and display of images. Media data, such as artwork images, are users' most desired data. In particular, it is undesirable to take a long time to load images of artworks when deploying into applications such as virtual museums. To address this issue, individual archives can provide media data in different sizes, such as simple, normal, and maximum sizes, allowing applications to select the appropriate size data based on the intended use. The Integrated API should also be able to provide corresponding images in this way. As an alternative measure, media data converted to a smaller size could be maintained as cache data in each application.

6 Conclusion

The Global Art Collection Archive (GACA) is proposed as a method for globally integrating art collections of various museums to provide accessibility through GACA API. By connecting the individual museum archives to dictionaries such as artist names, GACA enables the dynamic curation, integration, and use of these art collections in a variety of applications, including virtual reality, data sensorium, and digital fabrication.

However, there are still challenges to be addressed in the future. These include finding ways to extract specific artworks from the large volume of collection data and storing and providing media data of artworks in appropriate sizes.

The most significant future effort is to create a viewing environment based on GACA that allows users to experience the creativity of artworks. We envision this environment not just as a place to view artworks, but as a space where users can fully engage with and be inspired by the artworks through seeing, feeling, and knowing them. We hope that this challenging effort will open a new era of creativity and innovation.

Acknowledgment

Without collaborative research partnership between Musashino Unviersity and Ishibashi Foundation, this research would not even exist. We would like to express our utmost gratitude to Hiroshi Ishibashi, Taiji Nishijima, Kazunori Yamauchi, Shoji Kometani and Tomohiro Kawasaki of Ishibashi Foundation for their great cooperation and support throughout the project period.

References

[1] The Metropolitan Museum of Art: The Met Collection, available via WWW, https://www.metmuseum.org/art/collection (2022)

[2] Paris Musées: Les collections en ligne des musées de la Ville de Paris , available via WWW, https://www.Paris Muséescollections.paris.fr/ (2022).

[3] Musée du Louvre: Atlas database of exhibits, available via WWW, http://cartelen.louvre.fr/ (2021).

[4] Kitagawa, T. and Kiyoki, Y.: "The mathematical model of meaning and its application to multidatabase systems," Proc. 3rd IEEE Int. Workshop on Research Issues on Data Engineering: Interoperability in Multidatabase Systems, p.130–135 (1993).

[5] Kiyoki, Y. and Kitagawa, T.: "A metadatabase system supporting interoperability in multidatabases", Information Modeling and Knowledge Bases, Vol.5, pp.287–298 (1993).

[6] Kiyoki, Y., Kitagawa, T. and Hitomi, Y.: "A fundamental framework for realizing semantic interoperabil- ity in a multidatabase environment", Journal of Integrated Computer-Aided Engineering, Vol.2, No.1, pp.3–20 (1995).

[7] Kiyoki, Y., Hosokawa, Y. and Ishibashi, N.: "A Metadatabase System Architecture for Integrating Het- erogeneous Databases with Temporal and Spatial Operations," Advanced Database Research and Devel- opment Series Vol. 10, Advances in Multimedia and Databases for the New Century, A Swiss/Japanese Perspective, pp.158–165, World Scientific Publishing (1999).

[8] Ishibashi, N.: "*Artizon Cloud:* A Multidatabase System Architecture for an Art Museum," Information Modelling and Knowledge Bases XXXIII, pp.323-331 (2022).

[9] Ishibashi, N., Fukuda, T., Tsuchiya, Y., Enzaki, Y., Iwata H.: "*Art Sensorium Project:* A System Architecture of Unified Art Collections for Virtual Art Experiences," *33rd International Conference on Information Modelling and Knowledge Bases EJC 2023.* (2023) (submitted)

[10] Iwata, H., Sasaki, S., Ishibashi, N., Sornlertlamvanich, V., Enzaki, Y., Kiyoki, Y.: "Data Sensorium: Spatial Immersive Displays for Atmospheric Sense of Place," Information Modelling and Knowledge Bases XXXIV, IOS Press, pp.247-257. (2022).

[11] Fukuda, T., and Ishibashi, N: "Virtual Art Exhibition System: An Implementation Method for Creating an Experiential Museum System in a Virtual space", Information Modelling and Knowledge Bases XXXIV, IOS Press, pp.38-47.(2022).

[12] Gershenfeld, N., Gershenfeld,A. and Cutcher-Gershenfeld, J.:"Design Reality: How to Survive and Thrive in the Third Digital Revolution", Basic Book (2017).

[13] Japan Search, available via WWW, https://jpsearch.go.jp/ (2022).

[14] Heritage Connector, available via WWW, https://www.sciencemuseumgroup.org.uk/project/heritage-connector/ (2022)

[15] Google Arts & Culture, available via WWW, https://artsandculture.google.com/ (2022).

[16] Wikidata, available via WWW, https://www.wikidata.org/ (2022).

[17] Artizon Museum, available via WWW, https://www,artizon.museum (2022).