Federating Natural History Museums in Natural Europe

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Abstract. An impressive abundance of high quality scientific content about Earth's biodiversity and natural history available in Natural History Museums (NHMs) around Europe remains largely unexploited due to a number of barriers, such as: the lack of interconnection and interoperability between the management systems used by museums, the lack of centralized access through a European point of reference like Europeana, and the inadequacy of the current metadata and content organization. To cope with these problems, the Natural Europe project offers a coordinated solution at European level. Cultural heritage content is collected from six Natural History Museums around Europe into a federation of European Natural History Digital Libraries that is directly connected with Europeana.eu. This paper presents the Natural Europe Cultural Digital Libraries Federation infrastructure consisting of: (a) The Natural Europe Cultural Environment (NECE), i.e. the infrastructure and toolset deployed on each NHM allowing their curators to publish, semantically describe, manage and disseminate the Cultural Heritage Objects (CHOs) they contribute to the project, and (b) the Natural Europe Cultural Heritage Infrastructure (NECHI) interconnecting NHM digital libraries and further exposing their metadata records to Europeana.eu.

Keywords: digital curation, preservation metadata, metadata aggregation, digital libraries, interoperability, Europeana.

1 Introduction

Countless cultural and biodiversity treasures are deposited in Natural History Museums across Europe, many hidden away beyond easy access. Bringing them to light requires solutions able to overcome a number of barriers such as: the lack of interconnection and interoperability between the management systems used by museums, the lack of centralized access through a European point of reference like Europeana, as well as the inadequacy of current content organization and the metadata used.

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The Natural Europe project [15] offers a coordinated solution at European level that aims to overcome those barriers improving the availability and relevance of environmental cultural content for education and life-long learning use, in a multilingual and multicultural context. Cultural heritage content related to natural history, natural sciences, and nature/environment preservation, is collected from six Natural History Museums around Europe into a federation of European Natural History Digital Libraries that is directly connected with Europeana.

Needed to deal with a number of strong requirements for metadata management, and establish interoperability with cultural heritage, biodiversity and learning repositories, the Natural Europe project offers appropriate tools and services that allow the participating NHMs to: (a) uniformly describe and semantically annotate their content according to international standards and specifications, as well as (b) interconnect their digital libraries and expose their Cultural Heritage Object (CHO) metadata records to Europeana.eu.

This paper presents the Natural Europe Cultural Digital Libraries Federation infrastructure along with its tools and services consisting of: (a) The Natural Europe Cultural Environment (NECE), i.e. the infrastructure and toolset deployed on each NHM allowing their curators to publish, semantically describe, manage and disseminate the CHOs that they contribute to the project, and (b) the Natural Europe Cultural Heritage Infrastructure (NECHI) interconnecting NHM digital libraries and further exposing their metadata records to Europeana.eu.

2 The Natural Europe Cultural Digital Libraries Federation

In the context of Natural Europe, the participating NHMs provide metadata descriptions about a large number of Natural History related CHOs. These descriptions are semantically enriched with Natural Europe shared knowledge (shared vocabularies, taxonomies, etc.) using project provided annotation tools and services. The enhanced metadata are aggregated by the project, harvested by Europeana to become available through its portal and exploited for educational purposes.

The architecture of the Natural Europe Cultural Digital Libraries Federation, presented in Fig. 1, consists of the following main components (further described in the next sections):

- The *Natural Europe Cultural Environment (NECE)*, referring to the toolset deployed at each participating NHM, consisting of the Multimedia Authoring Tool (MMAT) and its underlying repository (CHO Repository). It facilitates the complete metadata management lifecycle: ingestion, maintenance, curation, and dissemination of CHO metadata. NECE also specifies how legacy metadata are migrated into Natural Europe.
- The *Natural Europe Cultural Heritage Infrastructure (NECHI),* interconnecting NHM digital libraries and further exposing their metadata records to Europeana.eu. Moreover, NECHI provides services for searching and accessing all museums' CHOs from a single point.
- *Search Widgets* for Natural Europe and Europeana cultural material search, supporting simple, faceted or connected search (on Natural Europe and Europeana).

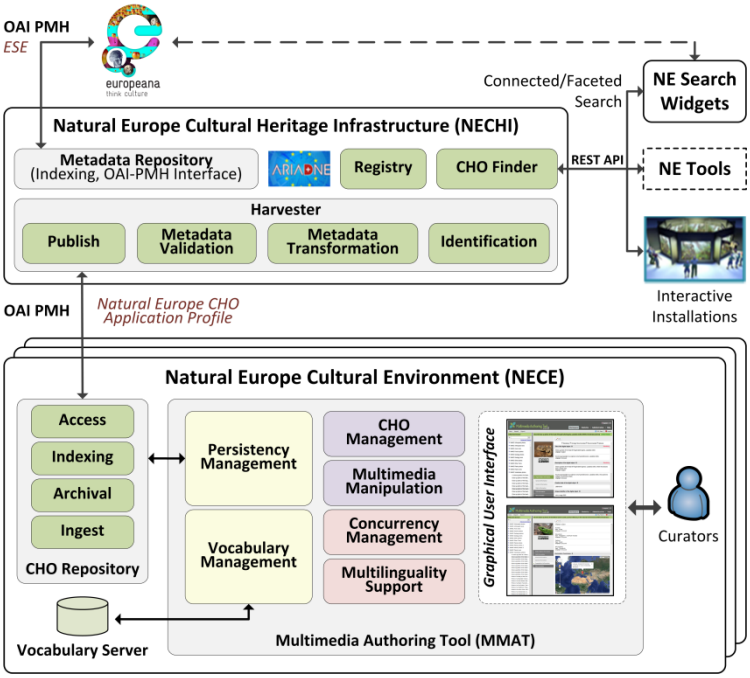

Fig. 1. The Natural Europe Cultural Digital Libraries Federation Architecture

3 Natural Europe Cultural Environment (NECE)

The Natural Europe Cultural Environment (NECE) [12], as presented in Fig. 1, refers to the toolset deployed at each participating NHM, which consists of the Multimedia Authoring Tool (MMAT) and the CHO Repository. These tools support the complete metadata management life-cycle: ingestion, maintenance, curation and dissemination of CHO metadata. The systems comprising NECE support a rich metadata element set, the Natural Europe CHO Application Profile. A brief description of the MMAT and the CHO Repository is presented in Sections 3.1 and 3.2, while Section 3.3 presents the Natural Europe CHO Application Profile.

3.1 Multimedia Authoring Tool (MMAT)

MMAT is a multilingual web-based management system for museums, archives and digital collections, which facilitates the authoring and metadata enrichment of Cultural Heritage Objects[1]. It supports the Natural Europe CHO Application Profile, as well as a variety of the most popular multimedia formats. The main features of MMAT include the publication of multimedia objects, the semantic linkage of the described

[1] A demo version of MMAT is available at:
`http://natural-europe.tuc.gr/music/mmat`

objects with well-established controlled vocabularies and the real-time collaboration among end-users with concurrency control mechanisms. Additionally, it provides the means to directly import the museums' legacy metadata for further enrichment and supports various user types with different access rights. The main modules of MMAT are the following:

- The *Graphical User Interface* is responsible for the interaction with the user, the presentation of the information as well as the communication with the server. It adopts the Google Web Toolkit (GWT) [10] technology and follows the Model-View-Presenter (MVP) [17] design pattern.
- The *CHO Management* module is responsible for the creation, retrieval, update and deletion of CHOs, CHO records/collections and users.
- The *Multimedia Manipulation* module manages all the functionality concerning the multimedia files in the system. This includes the generation of thumbnails and the extraction of metadata from media files, which are used for the creation and enrichment of CHO records.
- The *Concurrency Management* module provides the basic functionality for concurrent access to the data on the repository. It ensures that there are no consistency problems when multiple users try to access the same resource by providing methods for acquiring/releasing/refreshing locks on a CHO record/collection.
- The *Vocabulary Management* module enables the access to taxonomic terms, vocabularies, and authority files (persons, places, etc.). This information resides on the Vocabulary Server, providing indexing and search capabilities.
- The *Persistency Management* module manages the submission/retrieval of information packages to/from the CHO Repository.

3.2 CHO Repository

The CHO Repository is responsible for the ingestion, maintenance and dissemination of both content and metadata. It adopts the OAIS Reference Model [11] and accommodates modules for the ingestion, archival, indexing, and access of information packages, i.e., CHOs, CHO records/collections, and user information.

The *Ingest Module* receives, validates, processes and finally transfers the information packages submitted by the MMAT to the Archival Module in order to be stored/updated/deleted to the CHO Repository.

The *Archival* and *Indexing Modules* serve information package storage and retrieval requests submitted by the Ingest and Access Modules respectively. They maintain (preserve and index) content and metadata by employing an eXist XML database and an Apache SOLR Indexer.

The *Access Module* exposes a number of services to the MMAT and the Natural Europe Harvester in order to retrieve information stored in the CHO Repository. As regards to the MMAT, the module provides functionality for applying access control policies and performing fast search/retrieval operations by exploiting indices maintained by the Indexing module. Concerning the Natural Europe Harvester, the module

offers an OAI-PMH interface, allowing NHMs to expose their metadata to NECHI and subsequently to Europeana.

3.3 Natural Europe CHO Application Profile

The Natural Europe CHO Application Profile [14] is a superset of the Europeana Semantic Elements (ESE) [8] metadata format. It has been developed through an iterative process involving the NHMs' domain experts and the technical partners of the project, driven by the needs and requirements of the stakeholders and the application domain of the project.

The Natural Europe CHO Application Profile consists of the following parts:

- The *Cultural Heritage Object (CHO) information* that provides metadata information about the analog resource or born digital object (specimen, exhibit, cast, painting, documentary, etc.). It is composed of the following sub-categories:
  - The *Basic information*, which deals with general descriptive information (mostly scientific) about a Cultural Heritage Object.
  - The *Species information*, that is applicable to describe information related to the species of a described specimen (animals, plants, minerals, rocks, etc.) in the context of Natural Europe.
  - The *Geographical information*, which contains metadata for the location in which a specimen has been collected.
- The *Digital Object information*, that provides metadata information about a digital (photo, video, etc.) or digitized resource (scanned image, photo, etc.) in the context of Natural Europe. It is composed of the following sub-categories:
  - The *Basic information*, that deals with general descriptive information about a digital or digitized resource.
  - The *Content information*, which is related to the physical characteristics and technical information exclusive to a digital or digitized resource (URL, Content Type, Format, Extent, etc.).
  - The *Rights information*, which describes the intellectual property rights and the accessibility to a digital or digitized resource.
- The *Meta-metadata information*, that provides metadata information for a CHO record. These include the creator of the record in the Multimedia Authoring Tool, the different languages that appear in the metadata, etc. Additionally, it describes the history of the record during its evolution in the MMAT, including the operations and entities that affected it.
- The *Collection information*, that provides metadata information for logical groupings of contributed CHOs within a museum.

Fig. 2 presents a simplified example of a CHO record taken from the Natural History Museum of Crete (NHMC), described using the Natural Europe CHO Application Profile.

```
<record xmlns="http://www.natural-europe.eu/nhm/aip/">
  <objectUri>http://nhmc.natural-europe.eu/12dda2d5</objectUri>
  <contextUri>http://www.nhmc.uoc.gr/museum/40319</contextUri>
  <contentType>IMAGE</contentType>
  <licenseUri>http://creativecommons.org/licenses/by-nc-nd/3.0</licenseUri>
  <scientificName xml:lang="la">Canis lupus</scientificName>
  <classification xml:lang="la" annotation="FAMILIA">Canidae</classification>
  <classification xml:lang="la" annotation="ORDO">Carnivora</classification>
  <classification xml:lang="la" annotation="CLASSIS">Mammalia</classification>
  <classification xml:lang="la" annotation="REGNUM">Animalia</classification>
  <commonName xml:lang="el">Λύκος</commonName>
  <commonName xml:lang="en">Wolf</commonName>
  <title xml:lang="en">Wolf, Canis lupus</title>
  <title xml:lang="el">Λύκος, Canis lupus</title>
  <creator xml:lang="en" annotation="Photographer">Trichas, A.</creator>
  <creator xml:lang="el" annotation="Φωτογράφος">Τριχάς, Α.</creator>
  <subject xml:lang="en">Mammals</subject>
  <subject xml:lang="el">Θηλαστικά</subject>
  <description xml:lang="en">Photo of wolves in forest diorama in the Paranesti NHM.</description>
  <description xml:lang="el">Φωτογραφία λύκων σε διόραμα δάσους στο ΜΦΙ στο Παρανέστι.</description>
  <contributor xml:lang="en" annotation="Curator">Lymberakis P.</contributor>
  <contributor xml:lang="el" annotation="Συγγραφέας μεταδεδομένων">Λυμπεράκης, Π.</contributor>
  <type xml:lang="en">Preserved specimen</type>
  <type xml:lang="el">Συντηρημένο δείγμα</type>
  <format>image/jpeg</format>
  <identifier>nhmc.image.40319</identifier>
  <rights annotation="Rights Reserved - Free Access">Natural History Museum of Crete ©</rights>
  <alternative xml:lang="en">Photo of Canis lupus</alternative>
  <alternative xml:lang="el">Φωτογραφία ενός Canis lupus</alternative>
  <extent>500 x 323 pixels</extent>
  <spatial xml:lang="en" annotation="Country">Greece</spatial>
  <spatial xml:lang="el" annotation="Χώρα">Ελλάδα</spatial>
  <geolocation latitude="35.296227084320144" longitude="23.91901402771254"/>
</record>
```


Fig. 2. A CHO record conforming to the Natural Europe CHO Application Profile

4 Natural Europe Cultural Heritage Infrastructure (NECHI)

The Natural Europe Cultural Heritage Infrastructure for metadata aggregation (presented in Fig. 1) has been based on the ARIADNE technologies and services [2]. ARIADNE is a standards-based technology infrastructure that allows the publication and management of digital learning resources in an open and scalable way. The components of the ARIADNE infrastructure have been appropriately configured in order to support the aggregation of NHMs CHO metadata based on Natural Europe CHO Application Profile. These are presented in the following sections.

4.1 Natural Europe Harvester

The Natural Europe Harvester is based on an ARIADNE Harvester instance, which has been deployed and configured to manage the harvesting of the metadata records provided by Natural Europe content providers. The Natural Europe Harvester uses OAI-PMH for harvesting the metadata from the OAI-PMH targets and publishes them to a central repository through the publish service. The Natural Europe harvester integrates the following services:

- **Publish Service.** For the publishing of the harvested metadata into a central repository, the Simple Publishing Interface (SPI) specification [20] has been used. The SPI provides a simple lightweight protocol for publishing data and metadata to a repository. In the context of Natural Europe, the 'source' is the Natural Europe harvester and the 'target' is the metadata repository that acts as an adapter to the publishing API.
- **Transformation service.** The transformation service converts metadata from the Natural Europe CHO Application Profile format to Europeana/ESE specification format in order to allow the aggregated CHO records of the participating Natural History Museums to be accessed by the Europeana.eu.
- **Identification service.** Provides persistent digital identifiers to resources in the ARIADNE infrastructure. The HANDLE system is used as the backend service to create globally unique, persistent and independent identifiers. This system allows the assignment, management and resolution of persistent identifiers in a distributed environment.
- **Metadata validation service.** Provides syntactic and semantic validation of metadata instances against predefined application profiles, in this case based on Natural Europe CHO Application Profile. The validation service combines different validation techniques including XSD schema, Schematron rules, and validation of vcards present in the metadata with a separate vcard parser or validator. With the validation service one single metadata record or all records exposed through OAI can be validated against the appropriate scheme. Reports are automatically generated.

4.2 Metadata Repository

The Metadata Repository, based on the ARIADNE Next Repository software, features both a metadata and file store where CHOs and metadata instances are persistently managed in an open and scalable architecture. Through several open standards and specifications it supports stable querying, publishing and harvesting of CHOs. It provides a flexible building block that can be adapted to different situations and that enables interoperability with external components (e.g., the harvester component).

The Repository supports indexing to enable efficient and fast search on top of large metadata collections using Apache Lucene. This text search engine library allows indexing all elements of the applied metadata scheme during their insertion in the repository enabling fast search on top of them. The Apache SOLR framework is being used to provide powerful, efficient and facetted search algorithms.

The Metadata Repository also offers an OAI-PMH target service in order to allow the metadata exposure. In the context of Natural Europe, this service is used by the Europeana.eu in order to access the aggregated metadata records of the participating Natural History Museums that have been transformed to ESE.

4.3 Registry Service

The ARIADNE Registry Service has been deployed and configured to hold information about the repositories that are included in the Natural Europe Cultural Federation.

The end user can review all the participating repositories and get information about them, e.g. their OAI-PMH target. Moreover, all the metadata related to a registered repository can be inspected, allowing the user to find information like the metadata formats supported by a repository.

4.4 Cultural Heritage Objects Finder

In order to let users search cultural material and browse the results, the ARIADNE Finder has been deployed and configured appropriately. The finder hides the protocols and standards that are used in the middle layer. It can also be exploited by any repository that supports REST-based APIs with JSON binding of LOM. The Natural Europe instance of the finder has been coupled on the Metadata Repository.

In order to enable efficient and fast search on top of large collections, the finder web tool takes advantage of the indexing services used in the backend Repository. Queries are submitted in JSONP format and results can be returned in both JSON and XML formats. All formulated queries are interpreted as conjunction of disjunctions.

For each repository (NECHI and Europeana) a search widget was implemented. The decision to have separate search widgets was based on the fact that, unlike the Natural Europe service, the Europeana search does not support faceted search through its web API. Two widgets have been implemented for each service: A standalone widget embeddable to any web page[2], and one embedded in the ROLE PLE (1.1)[3] [18] that can be used as a plugin in Moodle. The widgets can support three types of search:

- **Simple search**: The simple search queries the service corresponding to the widget for a given keyword or key phrase. For each result a summary is displayed.
- **Connected search**: The ROLE widgets allow the user to perform a joint search in both repositories: Europeana and Natural Europe. This functionality uses the IWC of the ROLE.
- **Faceted search**: As already stated, the faceted search functionality is only available in the Natural Europe widget and allows the filtering of the search results using facets (type, data provider, license, etc.).

5 Natural Europe Metadata Life-Cycle

The metadata life-cycle as defined by the Natural Europe Cultural Federation architecture comprises the metadata management and exploitation, and can be described in two steps.

During the first step, the curators of the NHMs prepare and manage the CHOs that they will contribute to the project using the tools and services provided by the NECE infrastructure. This step is divided in four phases:

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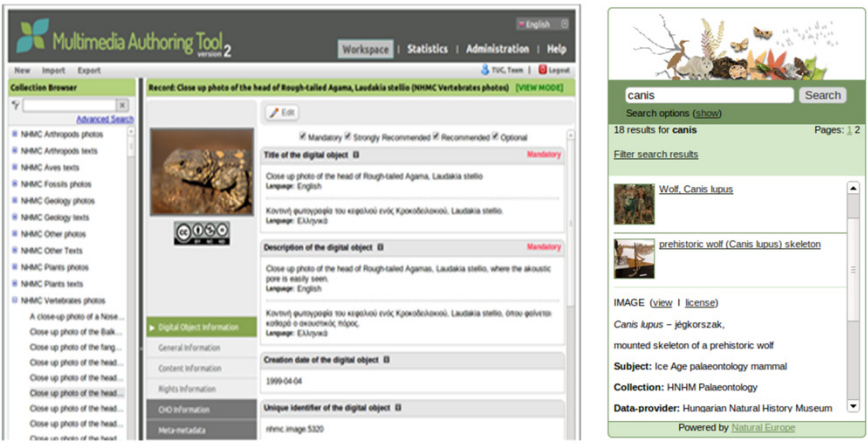
[2] `http://bit.ly/12ddc6T`

[3] Europeana Search: `http://bit.ly/181Z84Q`, Natural Europe Search: `http://bit.ly/181YZOT`

- In the **pre-ingestion phase** each NHM selects the CHO records/collections that will be contributed to the project and ensures that they will be appropriately migrated into Natural Europe.
- In the **ingestion phase** any existing CHOs and CHO descriptions are imported to the Natural Europe environment. The latter are further enriched through a semantic annotation process. Using MMAT (**Fig. 3**) museum curators can inspect, modify, or reject the imported descriptions.
- The **maintenance phase** refers to the storage and management of CHOs and CHO metadata using MMAT and the CHO Repository.
- The **dissemination phase** refers to the controlled provision of the maintained metadata to 3rd party systems and client applications, e.g. NECHI.

In the second step, the contributed CHOs from all the NHMs are harvested by the Natural Europe Harvester in NECHI. The collected metadata are indexed, validated, given persistent identifiers, and transformed to ESE. Subsequently, the metadata are disseminated to Europeana. Moreover, they are also exposed (through the Cultural Heritage Objects Finder) to 3rd party systems and Natural Europe applications, in order to be exploited for educational purposes. Finally, the participating NHMs or any other organization is able to embed the Natural Europe Search Widgets (**Fig. 3**) in its website in order to promote cultural heritage.



(a) (b)

Fig. 3. (a) The Multimedia Authoring Tool in use. (b) The Natural Europe Search Widget.

6 Deployment and Use

By today (3rd year of the project), a large number of CHOs have been published by each NHM using MMAT, exposed to the Natural Europe Cultural Federation and disseminated to Europeana, as presented in Table 1. Till the end of the project the total number of CHOs (last column) for each NHM will be reached.

Table 1. Number of CHOs published and to be published by each NHM

Museum	CHOs		
	Published	Remaining	TOTAL
Natural History Museum of Crete (**NHMC**)	2611	1399	**4010**
National Museum of Natural History – University of Lisbon (**MNHNL**)	1708	902	**2610**
Jura-Museum Eichstätt (**JME**)	1172	478	**1650**
Arctic Center (**AC**)	302	178	**480**
Hungarian Natural History Museum (**HNHM**)	3134	1076	**4210**
Estonian Museum of Natural History (**TNHM**)	1923	0	**1923**
TOTAL	**10850**	**4033**	**14883**

As far as MMAT is concerned, improvements of the user-interface and the search functionalities have been made after continuous feedback from museum partners in a number of tool releases. Heuristic evaluation of the MMAT was performed, while extensive usability studies have been and will be performed in a number of curator workshops organized by the participating NHMs [12], [19].

A cloud infrastructure is being supported over GRNET VIMA infrastructure and cloud versions of Natural Europe tools have been created. This way new NHMs can easily join Natural Europe and use its tools without any effort from their side.

7 Related Work

This section refers to related networks/federations and projects aiming at making available cultural and biodiversity resources coming from different providers/repositories. Moreover, it refers to tools related with the services provided by the NECE infrastructure for the description, management and dissemination of cultural/biodiversity content.

7.1 Cultural Heritage and Biodiversity Federations

The *Biological Collection Access Service for Europe (BioCASE)* [3] is a transnational network of biological collections of all kinds. It enables widespread unified access to distributed and heterogeneous European collections and observational databases using open-source, system-independent software and open data standards/protocols.

The *Global Biodiversity Information Facility (GBIF)* [9] is an international organization that focuses on making scientific data on biodiversity available via the Internet using web services. The data are provided by many institutions from around the world; GBIF's information architecture makes these data accessible and searchable through a single portal.

The *Opening Up the Natural History Heritage for Europeana (OpenUp!)* project [16] mobilizes the multimedia information using the existing information networks in the biodiversity research domain and links them to the Europeana.eu. Access is based on the established technical infrastructure of BioCASE that also feeds into GBIF.

Natural Europe has established close relations with BioCASE and OpenUp. In the context of Natural Europe, a framework for the connection of the Natural Europe NHMs' CHO repositories (federated nodes) to the BioCASE network has been developed and implemented (presented in [12]), exploiting mappings between the Natural Europe CHO Application Profile and the ABCD schema [1].

7.2 Tools for Description and Management of Cultural Content

CollectiveAccess [5] is a web-based multilingual cataloguing tool for museums, archives and digital collections. It allows integration of external data sources and repositories for cataloguing and supports the most popular media formats. Although it supports a variety of metadata standards (Dublin Core, PBCore, SPECTRUM, etc.), direct support for the ESE specification is not provided. Moreover, CollectiveAccess does not implement any harvesting protocol, thus is not possible to publish content to Europeana's web portal. Finally, the current version of CollectiveAccess lacks any importing mechanism, crucial in the case of museums having already described their cultural content with metadata in legacy or internal (museum specific) formats.

Collection Space [4] is a web-based application for the description and management of museum collection information. Collection Space does not support the ESE specification and its metadata dissemination mechanisms are limited (REST-API). Moreover, they do not support any harvesting protocol.

Custodea [6] is a system mainly intended for historical and cultural institutions that need to deal with digitization. It covers harvesting of digital content and representations, data transformation, creation and storage of metadata, vocabulary management, publishing and provision of data for Europeana and other institutions. However, the front-end application is desktop-based, which greatly complicates the collaboration of museum curators.

8 Conclusion and Future Work

We presented the architecture and deployment of the infrastructure used in the Natural Europe project, allowing curators to publish, semantically describe, and manage the museums' CHOs, as well as disseminating them to Europeana. This infrastructure consists of (a) the Natural Europe Cultural Environment (NECE), and (b) the Natural Europe Cultural Heritage Infrastructure (NECHI). It is currently used by six European NHMs participating in the Natural Europe project, where a large number of CHOs have already been published. A long term vision of the project is to attract more NHMs to join this effort. Technically, with the cloud infrastructure and the cloud versions of the Natural Europe tools this can be easily supported without effort from the NHM side.

A semantically rich cultural heritage infrastructure for NHMs is currently being developed, as a proof of concept that will give a Semantic Web perspective to the Natural Europe cultural content and will further support EDM [7].

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