SYNTHESYS+
Synthesis of Systematic Resources
a DiSSCo project

IMPLEMENTATION OF THE IIIF FOR NATURAL HISTORY COLLECTIONS
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Summary

IIIF (International Image Interoperability Framework) is an exchange standard for sharing multimedia representations of objects on-line. It has been adopted by many institutions and commercial partners in the digital humanities community but, before SYNTHESYS+, was not used in the Natural History community.

CETAF (Consortium of European Taxonomic Facilities) IDs are stable HTTP URIs identifying Natural History specimens on the internet.

SYNTHESYS+ is a European Commission funded project creating an integrated European infrastructure for natural history collections. This document is the final deliverable of Task 4.3 in Work Package 4: Digital Standards and Processes. Specifically, it addresses the goal of growing the network of Natural History IIIF providers by producing an implementation manual for IIIF and CETAF Identifiers in our community.

The motivations for adopting IIIF for Natural History image data are outlined. The characteristics of IIIF, as a standard and community of implementers, are layed out. Specific mechanisms for linking IIIF into existing data services are described. Finally, implementation case studies are presented. Clear recommendations are made throughout.

Although this document marks the official end of work on Task 4.3 the outputs of this part of SYNTHESYS+ will have a long-term positive effect on the way Natural History data is shared.

Description of Deliverable

Introduction

Researchers have become accustomed to online access to data about the specimens held in natural history collections. Over several decades metadata standards have been developed to facilitate the sharing and aggregation of these data, notably Darwin Core and ABCD (Access to Biological Collections Data) developed under the auspices of the Biodiversity Information Standards organization (TDWG) but other standards developed in other communities, have also proved useful, notably EML (Ecological Metadata Language) from the Ecological Society of America and Long Term Ecological Research Network, and GML (Geography Markup Language) from the Open Geospatial Consortium (OGC).

Data aggregators have arisen who both drive standards development and take advantage of the vast number of records made available through this community effort. Examples include Atlas of Living Australia, EoL (Encyclopedia of Life), iDigBio, GBIF (Global Biodiversity Information

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Facility) and WFO (World Flora Online). Aggregators with a wider cultural scope have also shown an interest in representing natural history material, notably JSTOR and Europeana.

In addition to these successes there are still many "dark specimens" that are not visible to the web and efforts continue to digitise data on these objects and expose it online.

The vast majority of the data that have been liberated so far have therefore been text based data about specimens and the exchange standards reflect this. But many institutions and projects have simultaneously been imaging their specimens, producing large numbers of images and other media associated with their specimens that they want researchers to be able to access.

Some existing standards have created media extensions to accommodate the sharing of images and other multimedia formats. However, these are restricted to metadata about media objects rather than the exchange of the media objects themselves. For example, two extensions to Darwin Core are Audubon Core, (Multimedia Resources Task Group 2013) which is designed to "determine whether a particular resource or collection will be fit for some particular biodiversity science application before acquiring the media." and the Simple Multimedia extension, which is a "simple extension for exchanging metadata about multimedia resources". Therefore image exchange, in particular, has not used open standards. Projects have relied on transferring high resolution versions of images (e.g. submission of type specimen images to JSTOR) or cut down compressed versions (e.g. many herbarium specimens submitted to The Global Biodiversity Information Facility (GBIF) or to Europeana).

The ad hoc network of institutions, organisations and projects that has emerged has not allowed access to high resolution versions of images as curated by the host institutions themselves beyond basic links to web pages. If high resolution images have been published in online catalogues, they have been made available using a hotchpotch of different technologies including the now defunct Java Applets and Adobe Flash player. The network has not supported different views of the same specimen or annotations of those views, or integration of audio and moving images.

Natural history collections are not isolated from each other. Most research has to be conducted across collections, because in most cases no one collection holds all the specimens on a taxon. Furthermore, there are many implicit and explicit links between collections. For example, botanical specimens are frequently created in duplicate and distributed to multiple herbaria[1]. In an ideal world a researcher should be able to view and annotate images of specimens held across multiple collections in a unified way, and the host institutions should have access to those annotations and statistics on how their specimens are being used. It should be as if the researcher had the specimens in their hands. How can we achieve this? How can we reduce the barrier to

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[1] N. Nicolson, A. Paton, S. Phillips and A. Tucker, "Specimens as Research Objects: Reconciliation Across Distributed Repositories to Enable Metadata Propagation," *2018 IEEE 14th International Conference on e-Science (e-Science)*, 2018, pp. 125-135, doi: 10.1109/eScience.2018.00028.

access created by history and geography? This also speaks to the Article 17 of the Convention on Biological Diversity on exchange of information. It states that "*The Contracting Parties shall facilitate the exchange of information, from all publicly available sources, relevant to the conservation and sustainable use of biological diversity, taking into account the special needs of developing countries*". Clearly, facilitating access to high quality images of biological specimens across the internet would at least partially resolve barriers to research in some of the most biodiverse countries.

The notion of sharing and annotating specimen images is not new to the natural history community. MorphBank, founded in 1998, has grown to allow much of this desirable functionality but at the cost and fragility of being a centralised database. The question we should perhaps be asking is: how can we make the biodiversity data sharing network as a whole more like MorphBank?

The sharing of multimedia representations of objects online is not a problem unique to the biodiversity community. Scholars in museums and archives of all kinds are facing the same issues. In 2011 the British Library, Stanford University, the Bodleian Libraries (Oxford University), the Bibliothèque nationale de France, Nasjonalbiblioteket (National Library of Norway), Los Alamos National Laboratory Research Library, and Cornell University came together to develop an exchange standard called IIIF (International Image Interoperability Framework - pronounced "Triple-Eye-Eff"). This framework now consists of six APIs (Application Programming Interface), five stable and one in beta, to publish and integrate image and other multimedia resources in a uniform manner. It has been adopted by many institutions and commercial partners in the digital humanities. Applications based on IIIF enable many of the features desired by biodiversity researchers.

This document is the culmination of an international project (SYNTHESYS+ Task 4.3) funded by the European Commission that has run from 2019 to 2021. The purpose of SYNTHESYS+ Task 4.3 was to encourage the use of IIIF as a standard way of sharing images of natural history objects and to link this to the CETAF specimen IDs already in use. The task did this by establishing exemplar implementations (subtask 4.3.1) and documenting our experiences in the form of a document to apply IIIF to other collections (subtasks 4.3.2 and 4.3.3).

The International Image Interoperability Framework (IIIF)

It can be daunting for a newcomer to reach an understanding of what IIIF is as it consists of a series of technical and social components working together towards three goals (from the IIIF website):

- To give scholars an unprecedented level of uniform and rich access to image-based resources hosted anywhere.

- To define a set of common application programming interfaces that support interoperability between image repositories.

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- To develop, cultivate and document shared technologies, such as image servers and web clients, that provide a world-class user experience in viewing, comparing, manipulating and annotating images.

The four components that make up IIIF in the broad sense are:

1. Technical standards in the form or Application Programming Interfaces (APIs).

2. Software applications including image viewers, server components and scripts that run in the background to publish image data.

3. The IIIF Consortium (IIIF-C), a membership organisation that provides steering and sustainability for the IIIF community. It comprises more than 40 Founding Members who have committed to support the growth and adoption of IIIF. It has a small paid staff and is most visible in organising workshops, conferences and training events.

4. The IIIF community which includes the adopters, users and developers of IIIF standards and software. By extension, dear reader, that includes you.

Here we will mainly discuss IIIF in the narrow sense of the APIs and software but these are just the concrete manifestation of the collaboration between individuals and institutions who maintain them. There are currently six distinct APIs. Below is a brief outline of what they do and how they interact with each other. The specifications themselves are quite accessible and provide full descriptions of each API.

> **Recommendation:** The most recent versions of the APIs are Version 3.0 for Image and Presentation and Version 1.0 for Authentication, Search and Change Discover. Adoption of these most current versions of APIs is recommended. Earlier versions are not discussed here.

IIIF APIs - Summary

Images are exposed to the world through a set of APIs. The **Presentation API** describes what the images are and how they relate to both each other and the object they are of - *so a human knows what they are looking at*. The **Image API** provides the pixels to display on the screen. The **Search API** makes it possible to find text within objects like books. There is an **Authentication API** in case you need to control who can see what and a **Change Discovery API** to keep track of modifications to big collections. The new kid on the block is the **Content State API** that enables you to direct someone to a particular place within a complex multimedia object.

But, as the Wizard Gandalf might say, "*The one API to rule them all, the one API to find them, the one API to bring them all, and in the darkness bind them*" is the Presentation API.

Image API

The Image API defines how a client application can retrieve the pixels of an image to display. It is similar to other image server APIs. Two types of call are specified. One returns a simple JSON

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based description of the image, such as its pixel dimensions, the other defines the syntax of a URI. This syntax can specify the region, size, rotation, quality characteristics and format of the image to be returned (Figure 1)
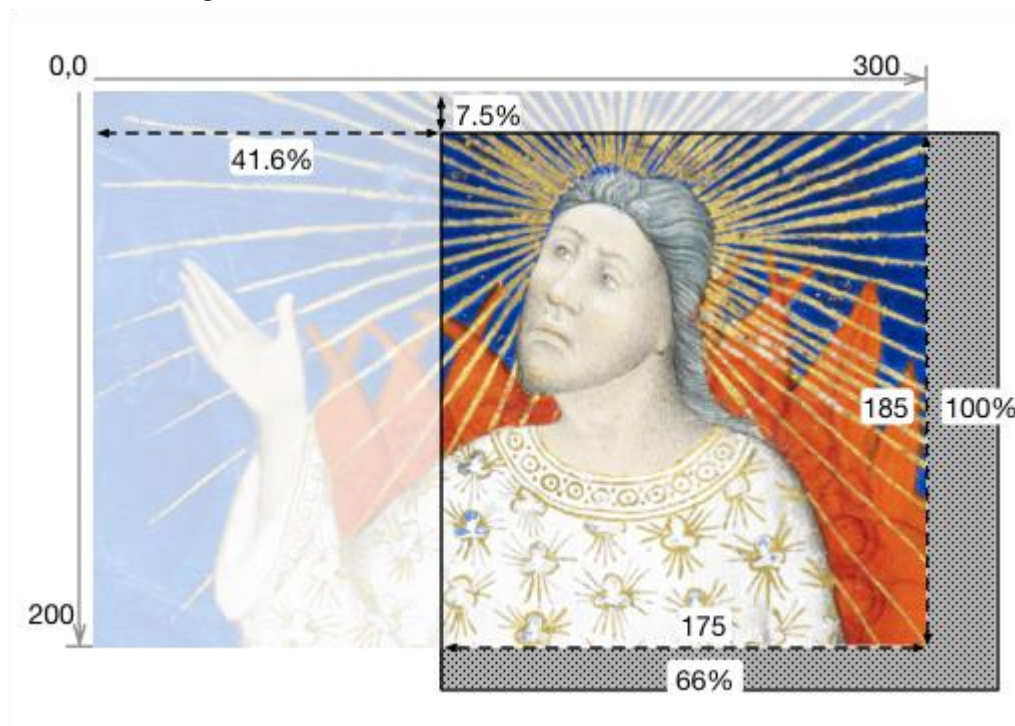

Figure 1: Example from Image API specification for a URI ending .../pct:41.6,7.5,66.6,100/max/0/default.jpg

One of the main uses of the Image API is to provide a tile service whereby the original image is divided into sub-images at various resolution levels. This allows the client application to zoom the image without downloading the whole file from the server.

An important feature of the Image API is the notion of Compliance Level. Although a suite of image manipulation features are specified, installations can implement a subset of these features and still be compliant. Level 0 compliance can be achieved with only static files and no dedicated software at all.

OpenSeadragon is a popular image viewer that can read image tile services provided by IIIF.

If IIIF only consisted of the Image API then it would not have made such a significant contribution to sharing images online. Image servers have had similar REST APIs for many years. Where IIIF goes further is in the Presentation API.

Recommendation: Because the Image API is so similar to APIs already provided by image servers it may be a good first step on the path to deploying IIIF on your collection. An existing image server may support publishing as IIIF Image API already (see the IIIF website for examples) or a wrapper script could be written to translate between the two (as is done for Djakota and FSI Servers)

> **Caution:** Don't stop here! It may be tempting to flick the switch on an image server to enable the Image API and feel the job is done but without the Presentation API in place the Image API offers few advantages over regular image servers. The minimum needed to integrate with others is to have both the Image API and the Presentation API running.

Presentation API

The IIIF Presentation API specifies how multiple images (and other media and data) relate to a real or virtual object and to each other. If we consider the case of a field notebook containing hand written observations associated with specimens in a museum. It may have many pages. The handwriting may not be legible to the unfamiliar and so providing a transcription is important. It may be desirable to provide translations to other languages and scholarly interpretation to make it useful for other researchers. The ordering of the pages and layering of annotations onto these pages isn't possible from a simple image server but requires some way to specify the relationships between these different pieces of data. This is what the Presentation API enables. From the specification:

> *"A compound object may comprise a series of pages, surfaces, or extents of time; for example the single view of a painting, the two sides of a photograph, four cardinal views of a statue, the many pages of an edition of a newspaper or book, or the duration of an act of an opera. This specification addresses how to provide an order for these views or extents, the references to the resources needed to present them, and the descriptive information needed to allow the user to understand what is being seen or heard."*

The syntax of the Presentation API is JSON-LD which combines the now ubiquitous JSON data exchange format with Linked Data principles. The result is a format that can be parsed by commonly available software libraries on all platforms and is also easy to interlink with other data. In addition to this the current version (3.0) has incorporated the W3C Web Annotation Data Model (with some caveats around the label property) allowing for extension and integration with generic annotation servers.

The data model (Figure 2) can appear daunting at first but is easily summarised.

- **Manifests** represent real world objects such as specimens or books.
- **Collections** define sets of Manifests and other Collections.
- **Canvases** are views of the object such as pages, sides, angles, different times.
- **Ranges** order Canvases such as page order.
- **Annotations** represent everything else. An image from an Image API service will be attached to a canvas as an annotation of that canvas. Text notes will be layered on in the same way. Annotations are further organised into pages and collections.

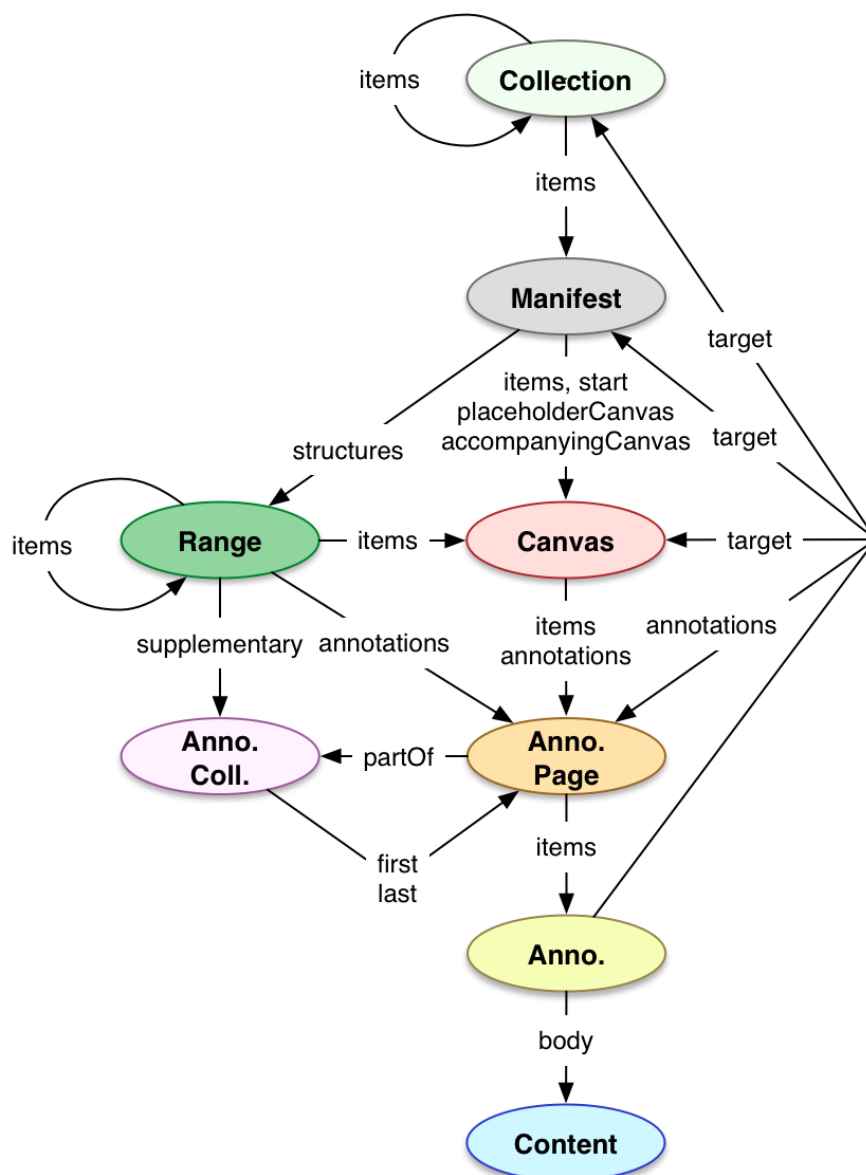See the full specification for a more detailed explanation of the structure.

Figure 2: Presentation API Data Model (from version 3.0 specification)

The Presentation API offers a specific implementation challenge because the data contained in a manifest file may need to come from more than one system within an institution. The curation of image files is often delegated to a generic Digital Asset Management system (DAM) separate from the database used to curate specimens in the collection. The DAM may be capable of exposing images using the Image API but not have the information needed to populate the labels in the Presentation API, data which is stored in the collection database. Likewise the collection database may have all the information for the labels but not know the dimensions to size the canvases. The system that publishes the Presentation API to the internet must be able to pull this information from wherever it is stored in the institution and this will require collaboration between systems and the people who run them.

Recommendation: At an early stage in implementation make sure that the people responsible for the relevant systems are involved and that they have the technical skills required. Pulling the data together shouldn't be technically challenging if the right people are involved.

Caution: Terminology can be confusing. The word **manifest** is used as a name for just about all Presentation API response documents. This is because usually there is one **Manifest** representing a single real world object in each file. But this is not always the case. A manifest file (response from the API) might contain Collections and multiple Manifests. Here Manifest (capital M) is used for the object and manifest (small m) is used in the loose sense of a IIIF Presentation API document.

Search API

Some IIIF objects (Manifests, Collections and Ranges) can contain large amounts of text. IIIF representations of books and newspapers are perhaps the examples that jumps to mind for this but even simple IIIF objects may contain multiple textual annotations. An image may have been OCR'd or transcribed and this text translated or interpreted by multiple scholars. There are therefore occasions where the user may want to search **within** a IIIF object. The Search API enables this.

Recommendation: Typical Natural History specimens have little text associated with them. Unless you have users who specifically require this functionality or are publishing manuscripts it is probably best to ignore the Search API during the initial roll out of IIIF.

Authentication API

Open access to content is desirable, but internal policies, legal regulations, business models, and other constraints can require users to authenticate and be authorized to interact with some resources. In IIIF this might also include access to certain zoom levels, adding watermarks to content or other measures. The IIIF Authentication API provides a guide to integrating existing authentication/authorisation systems within the IIIF viewer experience.

Recommendation: It is unlikely that the Authentication API will be needed during initial implementations of IIIF on Natural History collections because collections tend to default to open access. An exception is the obfuscation of location data on endangered species. This is already addressed by most collections only providing access on request to these records rather than requiring authentication for their whole collection. The Authentication API may be of importance in future rounds of implementation.

Change Discovery API

A Change Discovery API service describes changes to IIIF content resources and the location of those resources to harvest. Content providers can implement this API to enable the collaborative development of global or thematic search engines and portal applications that ultimately allow

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users to easily find and engage with content available via existing IIIF APIs. Change Discovery API is the most recent API to become stable (Version 1.0)

Recommendation: As discussed in the introduction the Natural History community has multiple metadata standards for aggregating specimen metadata. At this stage the Change Discovery API therefore seems redundant for our needs though may form a part of future network infrastructure.

Content State API

The Content State API provides a way of describing a Presentation API resource, or a part of a resource, in a compact format that can be used to initialize the view of that resource in any client that implements this specification. It provides the format of the "content state", and mechanisms for passing it between applications regardless of their user interfaces and capabilities.

Recommendation: The Content State API is still in Beta so it is not recommended for adoption at this point, unless it meets specific current needs.

Three Dimensional Models

Discussion here is focussed on two dimensional media. This is partly due to the predominance of herbaria within the project but also the current dominance of two dimensional images across many subdomains of Natural History. It is easier to start with flat photographs of objects and so that is what has been done. As it stands the IIIF Presentation API allows multiple views of three dimensional objects to be presented and related to each other. It is possible to present, for example, the dorsal, ventral, lateral views of an insect or focus stack slices from a diatom in a single manifest to great effect. There is, however, also active development in the IIIF community to bring true 3D modelling into the standard and an official community group to steer this.

Recommendation: If you have an interest in 3D modelling on Natural History objects using IIIF it may be worth joining the IIIF 3D Community Group.

Time Based Media

Most Natural History museum objects are static and can be represented by one or a few still images. Version 3 of the IIIF Presentation API does however support integration of time based media such as audio and video recordings and canvases can have durations as well as heights and widths. This has tremendous potential for publishing richer data sets such as timelines and annotated audio and video recordings. Unfortunately this is beyond the scope of this introductory document but there is an active IIIF A/V Community Group who may be able to provide support.

Recommendation: If you have an interest in time based media consider joining the IIIF A/V Community Group.

CETAF Specimen IDs

In the last few years stable HTTP URIs (URLs or IRIs) have been adopted by a number of major institutions as a robust mechanism to reference specimens held by natural history collections. The development of use of URIs for specimens is very much a community effort involving institutions mainly acting under the umbrella of the Information Science and Technology Commission (ISTC) of the Consortium of European Taxonomic Facilities (CETAF). Today many millions of specimens are referenceable using this approach.

One catalyst for adoption of URIs for specimens was a 2012 paper: **Hyam, R.D., Drinkwater, R.E. & Harris, D.J.** *Stable citations for herbarium specimens on the internet: an illustration from a taxonomic revision of Duboscia (Malvaceae)* Phytotaxa 73: 17–30 (2012). [PDF]. At time of publication it became clear a number of institutions were thinking along the same lines and CETAF now has a group dedicated to implementation of stable identifiers and are referred to as CETAF IDs. Documentation on the CETAF Wiki and a tester application is hosted by RBGE.

CETAF IDs are regular HTTP(s) URIs that follow W3C best practices and that hosting institutional repositories have committed to keeping stable for the foreseeable future. There are three levels at which CETAF IDs can be implemented.

1. Stable HTTP(S) URIs are created that resolve to a web page for each specimen in an institution's collection.
2. In addition to a web page being available a machine readable RDF metadata record is available and can be retrieved if the user agent requests a response in `application/rdf+xml` format.
3. The RDF response encodes application specific data ideally in the CETAF Specimen Preview Profile (CSPP).

CETAF IDs are therefore very easy to implement, at least to Level 1, for any institution that has the intention of maintaining a presence on the web for their collection catalogue. They are not suitable for institutions who do not have this intention or ability. CETAF IDs integrate well with IIIF endpoints as discussed below.

> **Recommendation:** Institutions should implement CETAF IDs if they haven't already as it will help make their specimens accessible now and in the future.

> **Recommendation:** Institutions implementing CETAF IDs at Level 2 and above should use the mechanism outlined below to link to their IIIF Resources.

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Persistence

There has been some discussion about persistence of CETAF IDs particularly by advocates of the use of Digital Object Identifiers (DOI). These discussions are not relevant here. If, at some point in the future, DOIs (or some other technology) are used for Natural History specimens they will have to redirect users to stable HTTP URIs like CETAF IDs to access the data held at those institutions. This is the same mechanism as used by journal article DOIs currently. All calls for journal article DOIs redirect to the publishers' websites. Software agents and humans will follow the same processes as outlined here for the foreseeable future.

Metadata - What goes where?

IIIF has been adopted in diverse domains across the digital humanities. It is used unchanged for 20th Century newspapers as well as medieval manuscripts, paintings and social history projects. Much of its flexibility is down to a single design feature. IIIF Manifests do not contain domain specific metadata. From the Presentation API specification:

> *"descriptive information is given in a way that is intended for humans to read, but not semantically available to machines. In particular, it explicitly does not aim to provide metadata that would allow a search engine to index digital objects"*

This means IIIF can be adopted without having to negotiate a shared metadata vocabulary for the application or integrate an existing domain specific vocabulary into the IIIF Presentation API. Both these activities can be significant hurdles to overcome when adopting a data transport format.

The first issue that arises from this approach is that there is no way for a client application to understand what the manifest is about. Are these images of a fish or a tree? All the label data is strictly for human consumption. This issue is addressed with use of the seeAlso property. For museum objects this might be a link to a CIDOC record. For books it might link to a MARC record. For Natural History specimens it can link to the CETAF ID for the record. It can also be used to link to human readable data like a web page or even another manifest.

The other issue that arises is how a user might find manifests of objects to render when they search on domain specific metadata. In Natural History that is likely to include taxonomic and other biological data. How does a data provider indicate that there is a IIIF manifest associated with a particular specimen? To facilitate this the domain specific metadata has to have a mechanism to link to the manifest location. This will be different depending on the metadata standard in use.

Below the best practice methods of linking between common metadata standards and IIIF resources and back again are outlined.

Linking HTML Page to IIIF Manifest

Humans are most likely to consume metadata as web pages in collection catalogues. In these situations IIIF data will usually be presented using an embedded IIIF viewer such as Mirador or Universal Viewer. If a zoomable image is all that is required then the OpenSeadragon viewer can be used on its own to present just the Image API, the metadata being presented in the rest of the catalogue page.

When viewers are used to embed resources in pages the user may not be aware that there is a IIIF resource associated with this specimen at all and therefore not aware that the image data could be used in other applications. It is therefore recommended to include a draggable IIIF icon as part of the metadata for the specimen. Clicking on the icon will open the IIIF resource in a new window or tab. Dragging the icon onto a suitable IIIF viewer adds it to that viewer. Figure 3 and Figure 4 give examples of the use of such an icons in the RBGE herbarium catalogue and JACQ systems.
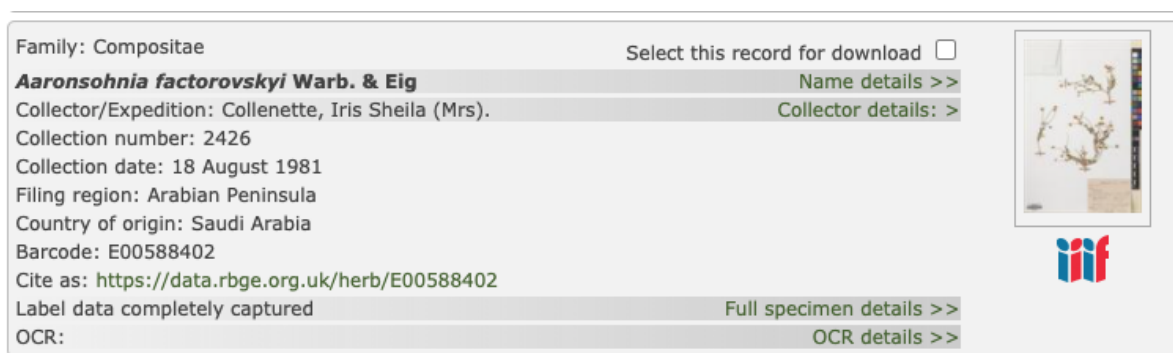
Figure 3: Screenshot from RBGE herbarium collection catalogue

Figure 4: Screenshot from JACQ system showing draggable IIIF icon

From the coding perspective such icons are simple to add. An example of the HTML code used is a follows

```
<a target="_blank"
href="mirador/?manifest=https://iiif.rbge.org.uk/herb/iiif/E00008781/manifest">
  <img
     src="logo-iiif.png"
     alt="IIIF Manifest"
     title="Click to use IIIF viewer or drag'n'drop to add to open viewer"
     draggable="true"
  >
</a>
```

Note that the HTTP URI in the href of the link must be a link to a viewer page that accepts the ?manifest= parameter. This means the host institution needs to provide a IIIF Viewer instance or access a publicly available instance.

> **Recommendation:** If an institution has implemented IIIF and has an online catalogue it should include draggable IIIF icons of this form on its catalogue web pages.

Linking IIIF Manifest to HTML Page

As mentioned above the seeAlso property is used within the IIIF Manifest to link to human readable data for the specimen. The CETAF ID makes a good link to the catalogue page for the specimen.

```
"seeAlso": [
  {
    "id": "https://data.rbge.org.uk/herb/E00588402#html",
    "type": "Text",
    "label": {
      "en": [
        "Catalogue page for this specimen."
      ]
    },
    "format": "text/html"
  },
  ...
],
```

Recommendation: Include a seeAlso resource in the Manifest resource object for the specimen with the id set to the CETAF ID for the specimen. Set the type property to "Text" and the format to "text/html". Append the anchor #html to the end of the URI.

Recommendation: Include an English language label for the link plus labels in as many other languages as appropriate for the collections location.

Linking IIIF Manifest to CETAF ID Metadata

The RDF metadata provided by the CETAF ID can be linked to in the same way as the catalogue page (see above).

```
"seeAlso": [
  ...
  {
    "id": "https://data.rbge.org.uk/herb/E00588402#rdf",
    "type": "Dataset",
    "label": {
      "en": [
        "Specimen description in RDF XML."
      ]
    },
    "format": "application/rdf+xml"
  }
],
```

Recommendation: If you implement CETAF IDs at Level 2 or above include a seeAlso resource in the Manifest resource for the specimen. Set the type property to "Dataset" and the format to "application/rdf+xml". Append the anchor #rdf to the end of the URI.

Recommendation: Include an English language label for the link plus labels in as many other languages as appropriate for the collections location.

Caution: The IIIF Presentation API requires each seeAlso id to be unique but CETAF IDs use content negotiation to provide the same data in multiple formats for a single URI. It is therefore necessary to create multiple unique URIs based on the CETAF IDs to express multiple formats in IIIF. Fortunately this can be achieved simply appending an # anchor to the end of the URIs. This is safe because the CETAF URI will not already contain an anchor (the specification stipulates not to include one) and the server will ignore any anchor when the URI is resolved. Meanwhile the URIs will appear as unique to software consuming the IIIF Manifest.

Linking CETAF ID Metadata to IIIF Manifest

We need a way to indicate to a machine that is ingesting CETAF ID metadata that there is a IIIF resource associated with the specimen being described. We do this by creating a typed link using the Dublin Core Relation property. This conceptually is very similar to the way the IIIF manifests use the seeAlso link. We describe an RDF resource that has the id of the IIIF Manifest URI and specify that the type of this resource is a IIIF manifest and the format is JSON-LD. It is possible to include any number of application specific properties here should that be necessary. The default example in the CETAF URI tester has a live example of how this is done (Figure 5).

```
<dc:relation>
 <rdf:Description rdf:about="https://iiif.rbge.org.uk/herb/iiif/E00421509/manifest">
   <dc:identifier rdf:resource="https://iiif.rbge.org.uk/herb/iiif/E00421509/manifest"/>
   <dc:type rdf:resource="http://iiif.io/api/presentation/3#Manifest"/>
   <dc:subject rdf:resource="https://data.rbge.org.uk/herb/E00421509"/>
   <dc:format>application/ld+json</dc:format>
   <dc:description xml:lang="en">A IIIF resource for this specimen.</dc:description>
 </rdf:Description>
</dc:relation>
```
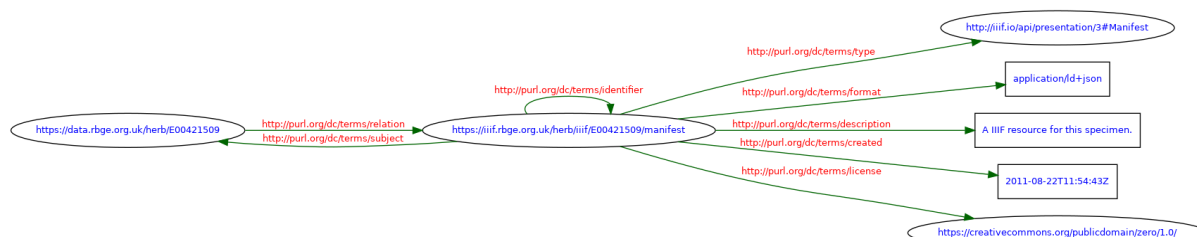

Figure 5: RDF Model of typed link to IIIF Manifest

> **Recommendation:** If you publish RDF metadata for your specimens include a dc:relation property that describes the IIIF Manifest with the dc:type `http://iiif.io/api/presentation/3#Manifest` and the dc:format `application/ld+json`

> **Recommendation:** Include an English language dc:description property in your rdf:Description plus dc:descriptions in as many other languages as are appropriate.

Linking Darwin Core Metadata to IIIF Manifest

Many institutions publish their data to GBIF and other data aggregators using the Darwin Core metadata standard and its extensions. During the course of the project we established a convention for using the Audubon Core multimedia extension to publish IIIF manifest locations through Darwin Core. The extension is used in essentially the same way as it would be for a JPEG file. The figure below shows an example of a Audubon Core extension in a Darwin Core Archive metadata file.

```
<extension
encoding="UTF-8"
fieldsTerminatedBy=","
linesTerminatedBy="\n"
fieldsEnclosedBy="""
ignoreHeaderLines="0"
rowType="http://rs.tdwg.org/ac/terms/Multimedia">
 <files>
<location>darwin_core_images.csv</location>
 </files>
 <coreid index="0"/>
 <field index="1" term="http://purl.org/dc/elements/1.1/type"/>
 <field index="2" term="http://purl.org/dc/elements/1.1/format"/>
 <field index="3" term="http://rs.tdwg.org/ac/terms/accessURI"/>
 <field index="4" term="http://rs.tdwg.org/ac/terms/associatedSpecimenReference"/>
 <field index="5" term="http://purl.org/dc/terms/identifier"/>
 <field index="6" term="http://purl.org/dc/terms/description"/>
 <field index="7" term="http://ns.adobe.com/xap/1.0/rights/Owner"/>
 <field index="8" term="http://purl.org/dc/terms/rights"/>
 <field index="9" term="http://purl.org/dc/elements/1.1/rights"/>
 <field index="10" term="http://purl.org/dc/elements/1.1/creator"/>
 <field index="11" term="http://rs.tdwg.org/ac/terms/serviceExpectation"/>
</extension>
```

In the associated CSV file (in this case darwin_core_images.csv) the columns for the manifests would contain "application/ld+json" in the third column (dc:format), the URI of the IIIF manifest in the fourth column (ac:accessURI) and "IIIF" in the twelfth column (ac:serviceExpectation).

This can be implemented using the GBIF Integrated Publishing Toolkit. All records in the Meise Botanic Garden Herbarium that have an image of the specimen (about 1.3 M images available at the time of writing) have 2 rows in the Audubon Core extension. The first row is describing the available JPEG file, the second row is including the IIIF manifest (Figure 6).

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Figure 6: Screenshot of the IPT of Meise Botanic Garden with the usage of the 'Audubon Media Description' extension.

This technique worked successfully and GBIF has added IIIF Icons to their portal interface (Figure 7).

Figure 7: Example of actionable IIIF Icon from RBGE data in GBIF data portal

> **Recommendation:** If you publish data using Darwin Core Archive format, please add the manifest locations using this method. They will then automatically appear in the GBIF portal as interoperable links and in the GBIF data API for incorporation into other applications.

Linking with ABCD Metadata

Images are provided in ABCD using the repeatable *MultimediaObject* node, meaning multiple objects per specimen can be provided in a single ABCD record. Thus, the IIIF manifest can be included in a similar way as for DarwinCore Archives - by adding another *MultimediaObject* entry equivalent to the Audubon Core extension record as in the example in Figure 8.

```
─<abcd:MultiMediaObject>
  ─<abcd:FileURI>
      https://herbarium.bgbm.org/data/iiif/BW11422010/manifest.json
  </abcd:FileURI>
  ─<abcd:ProductURI>
      https://iiif.bgbm.org/?manifest=https://herbarium.bgbm.org/object/BW11422010/manifest.json
  </abcd:ProductURI>
  <abcd:Format>application/json</abcd:Format>
  ─<abcd:IPR>
    ─<abcd:Licenses>
      ─<abcd:License language="en">
        ─<abcd:Text>
            Partial images provided by this server are released under the Creative Commons cc-by-sa 3.0 (generic)
            licence [https://creativecommons.org/licenses/by-sa/3.0/de/]. Please credit images to BGBM following our
            citation guidelines [https://ww2.bgbm.org/Herbarium/cite.cfm]. If you would like to use images in a format
            or resolution which is not provided here, please contact us (d.roepert[at]bgbm.org).
        </abcd:Text>
        <abcd:URI>https://creativecommons.org/licenses/by-sa/3.0/</abcd:URI>
      </abcd:License>
    </abcd:Licenses>
  </abcd:IPR>
</abcd:MultiMediaObject>
```

Figure 8: Example of RDF-XML of ABCD showing inclusion of IIIF Manifest link

This should allow GBIF to harvest IIIF manifests from ABCD in the same manner as for DarwinCore archives.

ABCD is also used for delivering multimedia objects to Europeana, the European virtual library for cultural objects, by OpenUp!, the natural history aggregator. Europeana already uses IIIF to incorporate images into the data portal, and Openup! is currently testing provision of IIIF manifests in the way described above (Figure 9).

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Figure 9: IIIF in Europeana's data portal: BGBM specimen provided using ABCD

Caution: Do not assume that providing a link to a IIIF manifest has to replace existing links to JPG and other media types. IIIF can be provided alongside existing mechanisms for sharing media objects. Even in new installations it may be convenient to also publish direct links to lower resolution JPG images so as to maximise compatibility. This could be achieved by linking directly to the IIIF Image API with a URI specifying an appropriate image size.

Linking from CSV download files

It is very common to exchange data as simple CSV files, often created or manipulated in spreadsheet programs such as Microsoft Excel. The problem with this approach is that the data in the columns isn't typed and the column headers are not standardised. It can be difficult for humans to know what the contents of a column represents. A standard column name is therefore proposed here.

Recommendation: When exchanging specimen data in CSV files the column that contains the URI of the IIIF Manifest associated with the specimen should be called **iiifManifestUri.**

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Case Studies

Royal Botanic Garden Edinburgh (RBGE) - Herbarium

The RBGE Herbarium contains approximately three million specimens. An online herbarium catalogue presents metadata on around one million of these and zoomable, high resolution images of about half of those. The specimen images are the result of a complex internal process that has developed over the last decade (Figure 10). The final stage of the process is to build an image tile pyramid of the specimen and store it in a ZIP file. A bespoke web service then exposes this data as Zoomify end point.
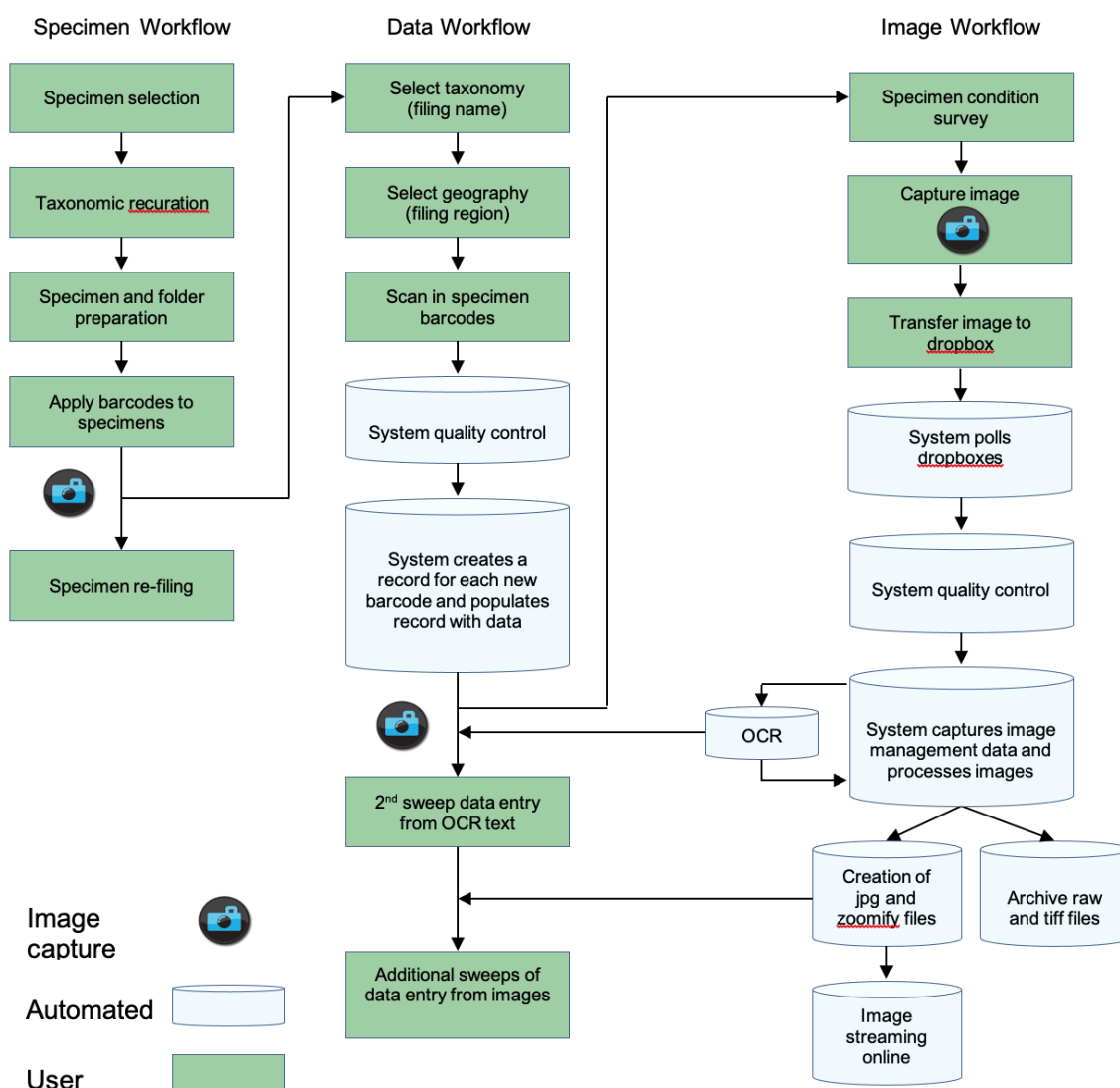

Figure 10: Digitisation workflow at RBGE

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The system works well and the online catalogue is used both within the organisation and by researchers from around the world. There was no need to make changes to the overall process however there were two areas that made adoption of IIIF desirable. Firstly the Zoomify endpoint restricts the choice of viewers in the catalogue. Secondly, because other herbaria do not use Zoomify in the same way, opportunities for interoperability were restricted.

Implementation

We therefore built our IIIF implementation as a wrapper around our existing infrastructure (Figure 11). A relatively simple set of bespoke PHP scripts (available in GitHub) implement the Image and Presentation APIs by calling the collections metadata in an Apache Solr index (the same one that feeds the catalogue) and the existing Zoomify API for images.
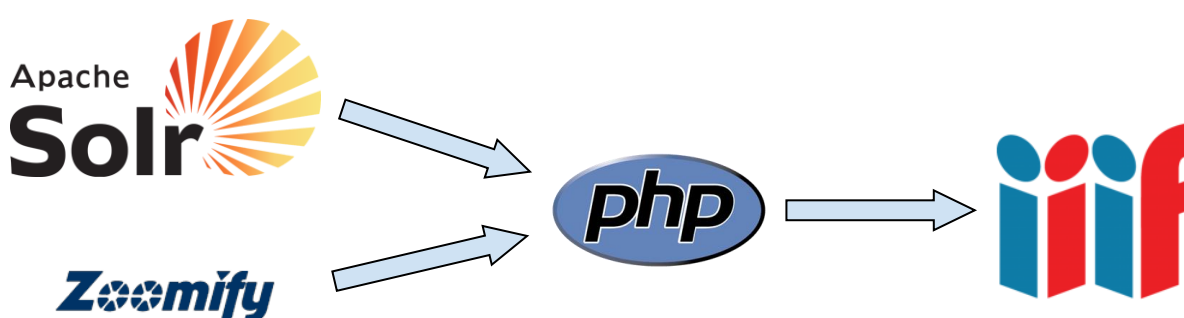

Figure 11: Data flow through PHP wrapper to serve IIIF at RBGE

Once the IIIF service was in place and proved to be stable the existing Zoomify viewer in the catalogue was swapped out for an OpenSeadragon viewer that calls the IIIF Image API. This means the catalogue and backend are further decoupled and we could switch either out in the future if that became desirable.

Having implemented the IIIF service we were able to add the manifest URIs to our Darwin Core Archive feed to GBIF using the mechanism described in the section above. This means our specimens are displayed in the GBIF data portal with draggable IIIF icons along with those from other collections. The manifests are also available through the GBIF API for incorporation into other applications.

Future development

Looking to the future we may be able to include OCR and Citizen Science data gathered about specimens as IIIF annotations. We also hope our specimens will be exploited in IIIF based taxonomic work benches.

Royal Botanic Garden Edinburgh - Padme

Padme is an RBGE in-house taxonomic data management/workbench system used to support floristic and monographic research within the institution. One of the key roles that Padme performs is to provide an integrated view between the specimen data held in our herbarium

collection management system and the specimen and field note data collected by individual researchers.

The RBGE herbarium catalogue is strictly limited to storing data relating to specimens stored in Edinburgh, as such it has a significantly more limited scope than Padme. Nevertheless, specimens collected by Edinburgh researchers will be stored in the RBGE herbarium, digitally imaged to a very high resolution, and recorded in the catalogue. It is therefore of significant advantage for researchers within Padme to be able to view the high-resolution specimen images alongside any images relating to that specimen stored in Padme. For example, it is common for RBGE staff to construct a montage of images documenting the specimen as it was found in the field and store them in Padme as well as the image of the dried voucher specimen taken by the herbarium.

Motivation for the Padme IIIF Image API implementation
Both the herbarium images and the images stored in Padme are available as Zoomify stacks. However, the APIs used to access those stacks were independently developed and somewhat different in character. IIIF offered a way to unify the APIs used to access images stored directly in Padme and those available via the Herbarium catalogue thus significantly simplifying the coding required to support viewing of the images.

Padme uses the OpenSeadragon viewer to display the zoomable images of objects stored in its datasets. Initially the OpenSeadragon configuration in Padme utilised the IIIF API for displaying the Herbarium images and the native zoomify tile stack viewing ability of the viewer to display the images stored directly in Padme. By implementing an IIIF image API endpoint as a wrapper around the existing Padme Zoomfiy stacks, images from both sources can be viewed simply by supplying a correctly formed URI to the viewer so that it can obtain the necessary info.json file.

Although it would only have been necessary to implement the IIIF Image API to achieve this goal, the concomitant advantages in terms of unified image sharing also made it worthwhile implementing a Padme specific IIIF Presentation API endpoint.

Padme IIIF Image API implementation
The implementation of the wrapper around the zoomify stacks was realised as a single PHP script and relatively straightforward to implement. Implementing the endpoint as a wrapper meant that all the existing code written to manage and build the stacks could be left unchanged. The only tricky part being the implementation of the logic required to recognise when a tile was being requested rather than an arbitrary region of the image. There is no mechanism in the IIIF URI scheme for explicitly requesting a tile. The current Padme IIIF Image API implementation is complete except that upscaling of image regions is not supported. Including implementation and testing, two working days were required to complete the work.

Padme IIIF Presentation API
Padme exposes three IIIF Presentation API endpoints to satisfy the three use cases for image access so far identified. These are implemented as three layers each with a standard form of URI and representing increasing levels of abstraction . As with the image API, the endpoint was

implemented as a set of PHP scripts. The hardest part of this section of the implementation was recreating the nested objects required to populate a manifest. Although not technically difficult to achieve, ensuring that the correct structure had in fact been created was not so trivial. In hindsight use of a third-party library in this respect may well have saved considerable time.

Layer 1: Access to a single image.

https://padme.rbge.org.uk/padmeweb/iiif/{imageid} – redirects to the manifest

https://padme.rbge.org.uk/padmeweb/{imageid} /manifest – returns the presentation API manifest for the image containing a single canvas for the image.

https://padme.rbge.org.uk/padmeweb/iiif/{imageid}/info.json - returns the Image API json file

https://padme.rbge.org.uk/padmeweb/{imageid}/{image/tileparams} – returns the pixel data from the specified region of the image as per the Image API specification.

Layer 2: Access to a set of images associated with an observation

http://padme.rbge.org.uk/padmeweb/iiif/{datasetid}/observation/{observationid} – redirects to the manifest

http://padme.rbge.org.uk/padmeweb/iiif/{datasetid}/observation/{observationid}/manifest – returns a Presentation API manifest with a canvas item for each image associated with an observation. Each canvas item will contain a URI of the form https://padme.rbge.org.uk/padmeweb/iiif/{imageid}/info.json i.e. a reference back to layer 1.

Layer 3: Access to a set of manifests associated with a species name

http://padme.rbge.org.uk/padmeweb/iiif/{datasetid}/species/{species_name} – redirects to the manifest

http://padme.rbge.org.uk/padmeweb/iiif/{datasetid}/species/{species_name}/manifest – returns a presentation API collection with an item for each observation associated with the requested species name. Each item in the collection contains a URI in the form http://padme.rbge.org.uk/padmeweb/iiif/{datasetid}/observation/{observationid}/manifest, i.e. a reference back to layer 2.

Note: Padme stores images from all datasets in a single image store. However, specimen, field note, and species records are stored within separate data sets corresponding to different projects within the Padme system. Therefore, only layer one URIs can be dataset agnostic.

Image sharing and Padme

Padme provides a content management system (CMS) that allows Padme users to present their data via the web (Figure 12). Within the CMS, images are presented either as part of a gallery or embedded within the results for searches on specimen data. Images displayed in the latter context include the IIIF drag 'n' drop logo using the Layer 2 manifest form described above thus facilitating open sharing of the images. The gallery facility is currently being rewritten and will include IIIF drag 'n' drop logos using the layer 1 manifest form.

Figure 12: Screen shot from the RBGE Begonia Resource centre displaying field images of the collection and a IIIF drag 'n' drop link.

Future development

The image handling in Padme will shortly be updated to allow Padme to act as a drop target for IIIF drag 'n' drop logos allowing Padme users to store references to plant images from external sources without requiring an explicit download of the image.

Herbaria Mundi

As mentioned above, one of the key things that botanists do is to compare herbarium specimens within and between herbaria. From the researchers perspective it would be ideal if all the specimens existed in a single herbarium, the one they were in. IIIF should allow this to happen, at least virtually, and Herbaria Mundi (World Herbarium) was set up as a demonstration of what such a system might look like.

Implementation

The system consists of an Apache Solr index of six hundred thousand specimens from RBGE and BGBM as well as a few stored in Zenodo. The index was built by polling the CETAF IDs for each specimen, indexing the associated specimen data and generating a thumbnail image from the IIIF end point for the specimen. Only specimens with associated IIIF Manifests were included in the index.

Users can log into the system using their [ORCID](#) IDs. They can then search and browse the specimens as if this were a catalogue of a single herbarium (Figure 13). Tools allow the specimens to be tagged and determined to species according to the current [World Flora Online](#) taxonomy and to compare sets of specimens side by side. The higher resolution images for zoom are all called live from the host institutions (Figure 14).
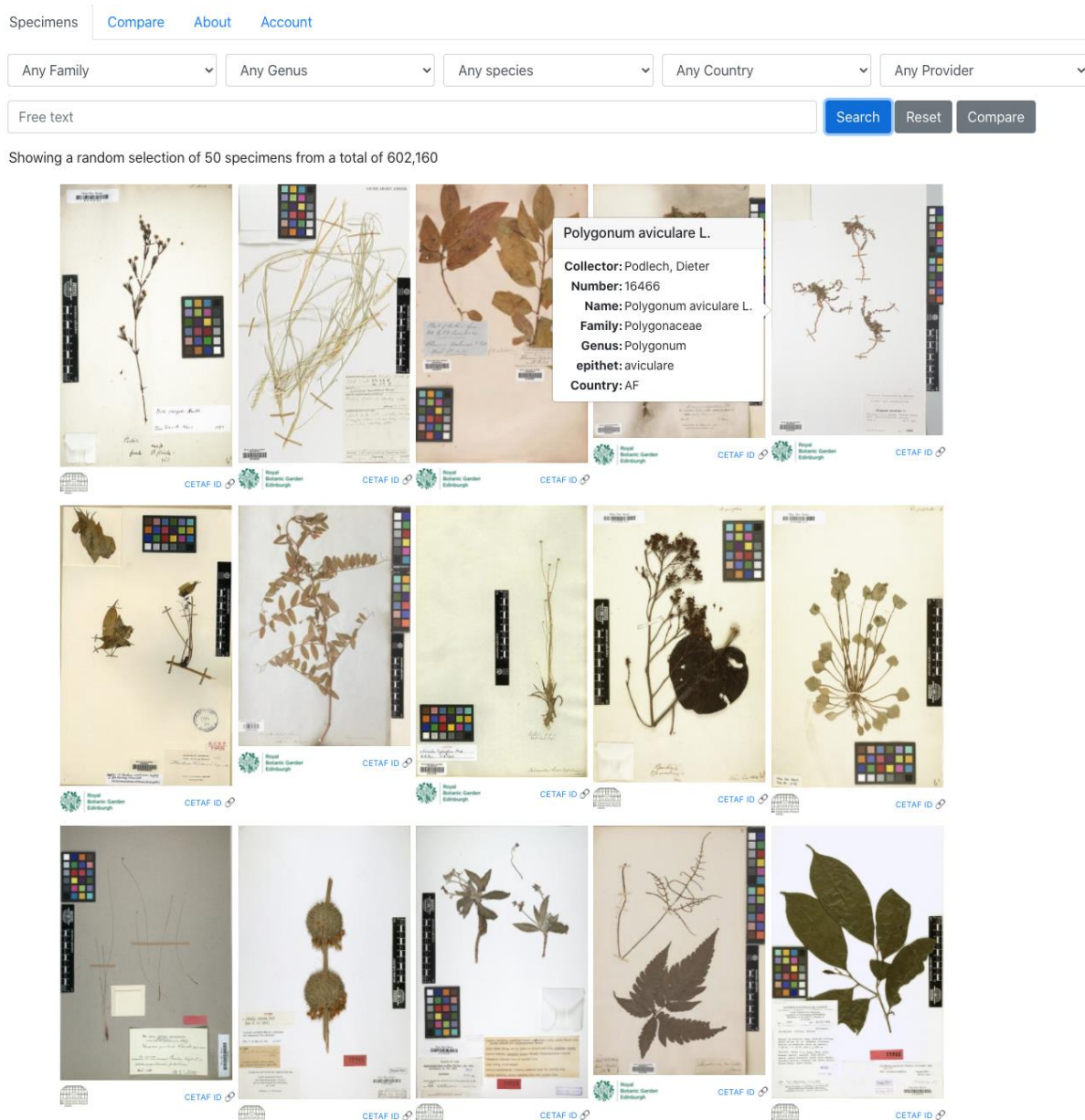

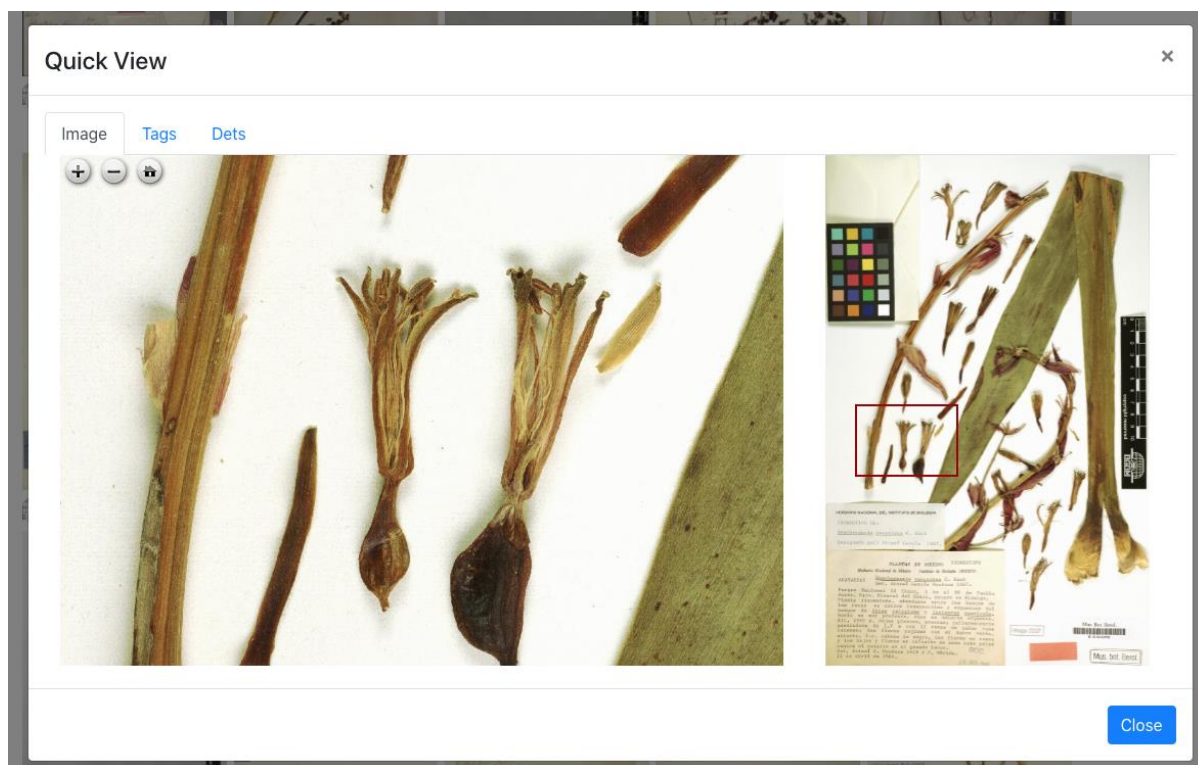*Figure 13: Search page within Herbaria Mundi*

Figure 14: Popup window in Herbaria Mundi pulling zoom data from the specimen's institution.

An issue that researchers face using such a system is incorporating specimens that are not available through CETAF IDs and IIIF. This may be because the specimens were only collected for identification purposes and will never enter a herbarium or have not been digitised yet. A demonstration was created where specimen images can be uploaded to the Zenodo repository and then presented through a caching server to Herbaria Mundi.

Future development

By the end of Task 4.3 Herbaria Mundi was acting as a good demonstration of how a single global herbarium might work (it was presented at TDWG 2020 conference) but it wasn't a complete production system. Going forward a number of design changes are required. At the start of the project IIIF Manifest URIs were not being indexed by GBIF but they are now. There is therefore no longer a need for Herbaria Mundi to build its own index, a task that is very resource intensive. It should be able to interact with the GBIF API to find specimens with associated IIIF Manifests. The Mirador viewer version 3 is now stable and the annotation plugin is being actively developed by the wider community. More features could be made available more quickly by switching to this viewer. It is planned to continue developing Herbaria Mundi along these lines.

Botanic Garden and Botanical Museum Berlin (B)

Since the beginning of digitisation at the BGBM in 1999, we have relied on zoomable image formats and software. The image format fpx was used for this. In the course of time, we had to use different commercial server software systems for on-the-fly provision of images, as there has been a discontinuation of software products over the last 20 years. Furthermore, there was hardly any software capable of both running in the cloud and managing extensive image inventories locally.

One of the main goals here was to enable variable image display in the different resolutions needed without having to do any prior image processing.

Three years ago, we started to provide all BGBM specimen images (~400,000) via an iiif server in parallel to the existing systems. The migration to iiif-only image delivery was completed in early 2020.

Implementation

Currently we use the IIIF server [digilib](#) for IIIF display of our images. The use of digilib gave us the possibility to use our existing image formats (tif, jpg) directly without having to do extensive conversions, because digilib can use jpeg directly via a plugin. The diglib server is integrated into our internal image management system as a publication server (Figure 15).
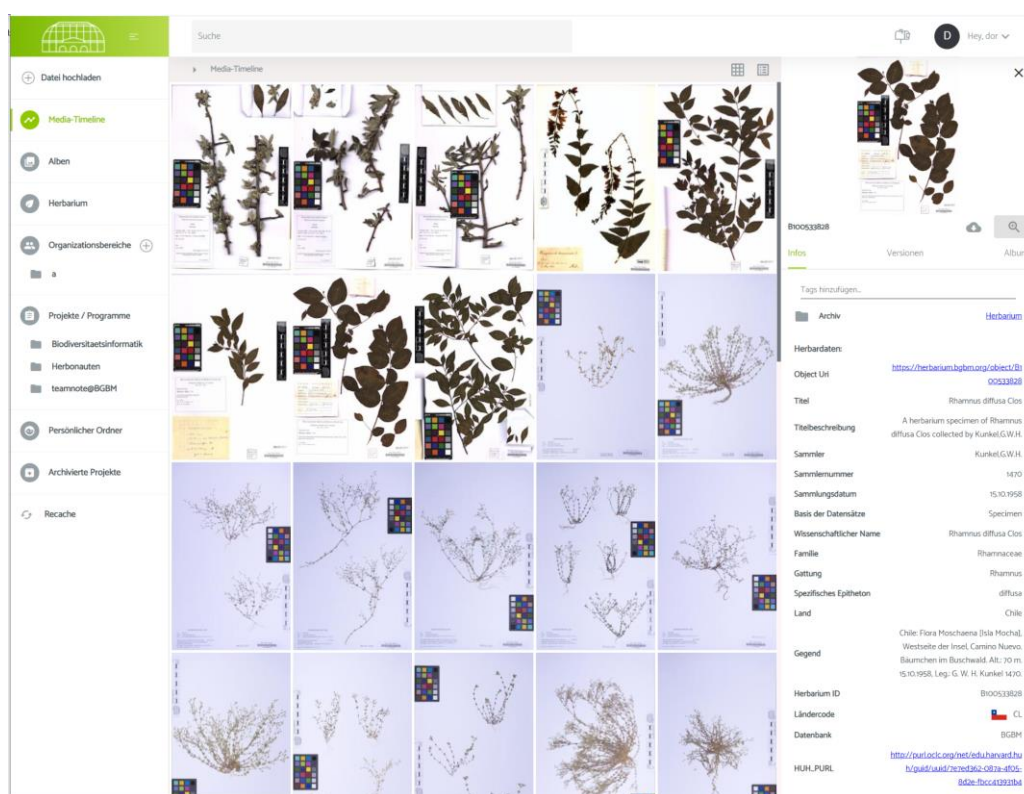

Figure 15: Screenshot of BGBM Internal image management system

In our portals we use the Mirador 2 viewer and the OpenSeadragon viewer. At the moment, all our IIIF outputs are implemented in APIs version 2.1. The creation of the manifest files is done in the context of content negotiation when requesting the corresponding endpoint. The underlying services and functions have been developed using the [SLIM PHP framework](#) based on scripts developed at the RBGE Edinburgh ([Code available in GitLab](#)).

We have recently started publishing the manifest file via our BioCASe Provider Software installations (see section Linking with ABCD Metadata) and we are testing the presentation in external portals such as GBIF and Europeana. The individual fields in the manifest file correspond to dwc fields and are filled on-the-fly from JACQ. We are offering this functionality to other

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herbaria that also manage their specimen data in JACQ as a service for making their associated images available via iiif.

Future development

As next steps we want to make further image sources (autographs, living specimens, archivals) available via IIIF services. We also plan to implement access to our IIIF elements via searches by name or person similar to the capabilities developed in Edinburgh.

The implementation of version 3 of the iiif API is also under way.

Museum für Naturkunde Berlin (MfN)

With the implementation of the Zukunftsplan, the collection of the Museum für Naturkunde Berlin with more than 30 million objects is being sustainably opened up as an international research infrastructure. The goal is to build an open, digital-analogue and internationally available collection infrastructure. The recently launched Data Portal is part of this process and promotes knowledge-based debates about the future of society and the relationship between humans and nature. At the time of its first release in early 2021, the Data Portal (Figure 16) already contains over 40,000 entries from three different sub-collections, which are now publicly accessible and usable for everyone interested.
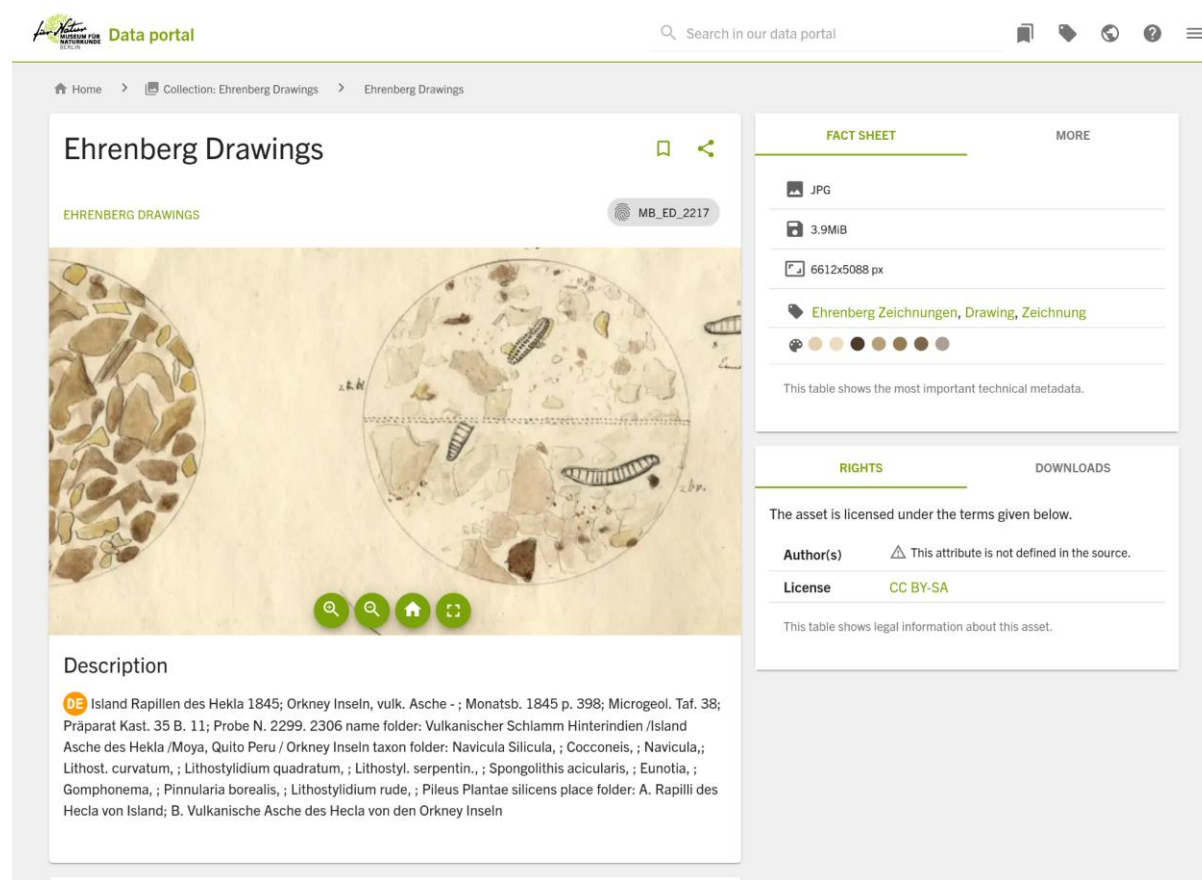

Figure 16: Screenshot of the Data Portal showing a drawing by Christian Gottfried Ehrenberg

Implemenation

To offer the best user experience all images are delivered through IIIF. Thus allowing users to smoothly zoom in and zoom out high-resolution images even when only a limited download bandwidth is available.

We use a range of technologies to offer IIIF integration. These include 3rd party tools and libraries as well as self-developed utilities. For example, all images are delivered by a self-developed IIIF server which is tightly integrated into our infrastructure and can serve WEBP images instead of JPEG images. For the frontend, we use the well-known OpenSeadragon library and customized IIIF viewers, namely Mirador and Tify.

Future development

In the future, we plan to reimplement our IIIF server to improve maintainability and to allow for better integration of upcoming technologies such as JPEG XL. Also, we will continue our contribution to community-driven projects such as Mirador or Tify.

Meise Botanic Garden

Meise Botanic Garden holds a herbarium with about 4 million specimens. During a first mass digitization program (DOE!) an initial set of 1.2 million specimens was imaged. Currently, a second program is expected to be finished by fall 2021 bringing the total number of specimen images to more than 2.4 million.

Digital data (including the images) are provided through the data portal botanicalcollections.be (Figure 17).

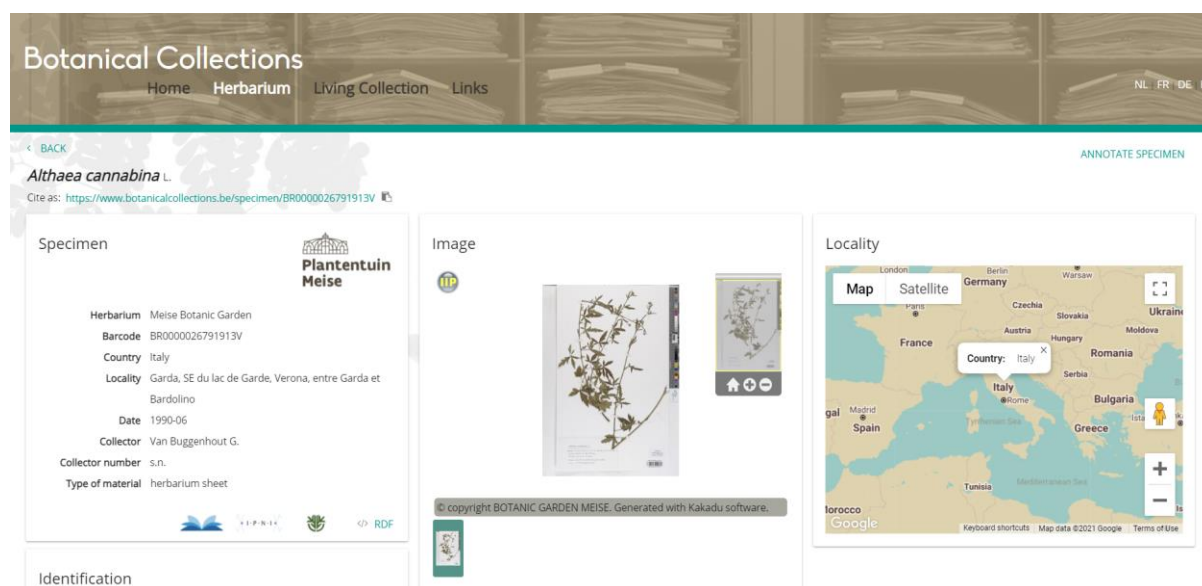*Figure 17: Screenshot of the data portal BotanicalCollections.be showing one of the digitized specimens.*

As a result of the digitization workflow, the specimen images are available in three different formats: high quality TIFFs, JPEG2000 and lower resolution JPG. The main purpose of the high

quality TIFFs is long term storage at MeeMoo. The herbarium portal is serving the JPEG2000 format.

Currently the lower resolution JPEG images are stored on a different server and are used to serve the Meise Botanic Garden herbarium dataset on GBIF. When developing the IIIF service, the least invasive option was to build a IIIF pilot based on the JPEG images (Figure 18).

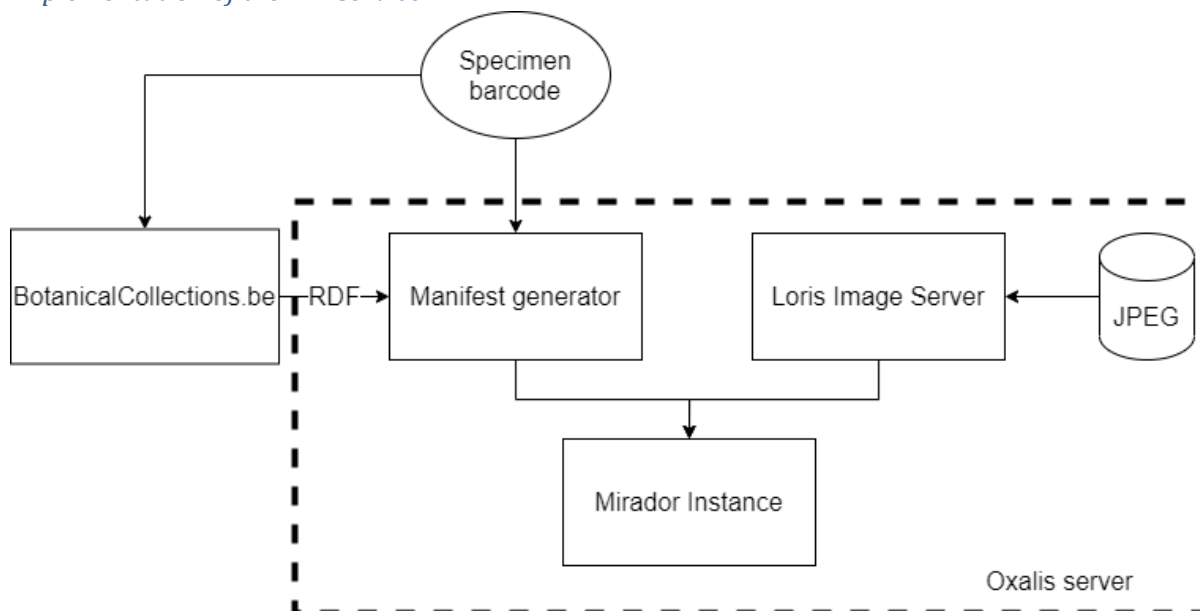*Implementation of the IIIF service*

Figure 18: Schematic overview of the current implementation of the IIIF service

At Meise Botanic Garden, version 2.1 of the IIIF image and presentation APIs is currently implemented. The pilot is based on an existing server which contains the (lower resolution) JPEG images. This has implications on the choice of the image server, since most servers don't support the use of JPEGs as an input format. In order to overcome this limitation, the choice was made to use the Loris image server. This is a python-based implementation that performs the tiling of the images on the fly. This made it easier to build upon existing infrastructure. However, there is a potential downside, since it might require much more computational power from the server side, especially when a large amount of requests are made to the server. An example of an image can be found here:

http://iiif-image.oxalis.br.fgov.be/V/BR0/000/025/668/070/BR0000025668070V.jpg/full/full/0/default.jpg

In order to generate the manifests, a python implementation is used as well (Code available on GitHub). Currently, the design is relatively straightforward and based on the unique barcode of each specimen. The barcode can be parsed and used to retrieve the URL to the image. The metadata that is transferred to the manifest is retrieved from the data portal botanicalcollections.be. Using the CETAF stable identifier (based on the barcode), it is possible to

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retrieve this metadata in a machine readable RDF format. An example of a manifest can be found here:

http://iiif-manifest.oxalis.br.fgov.be/specimen/BR0000025668070V/manifest

For demonstration purposes, a Mirador instance was installed on the same server and is available here:
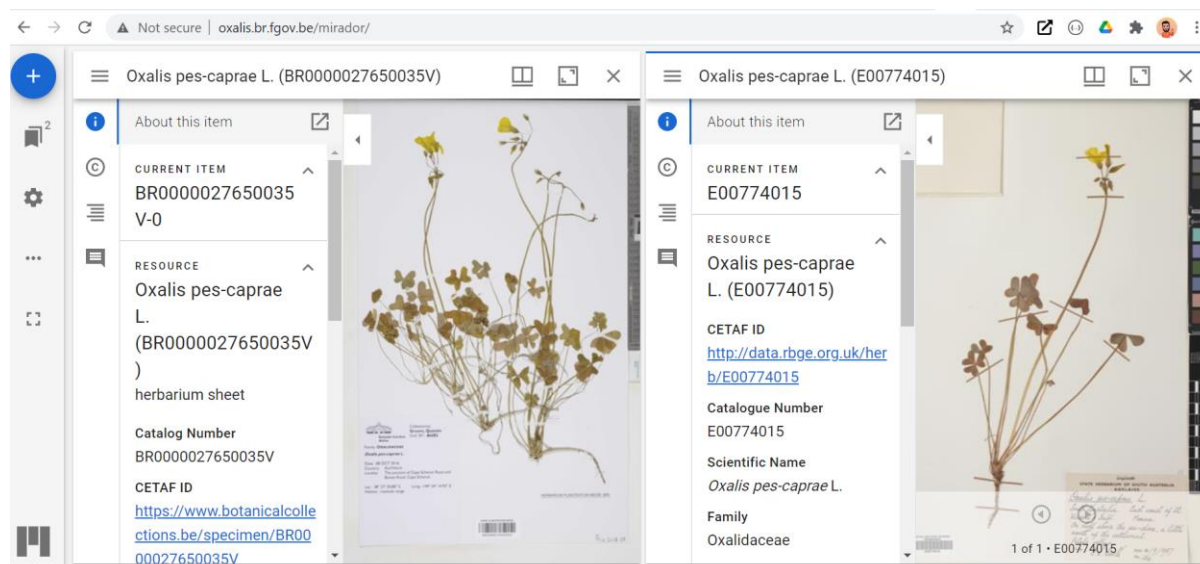
http://oxalis.br.fgov.be/mirador/

Figure xx: Screenshot the Mirador instance at Meise Botanic Garden. A IIIF image of a Meise specimen (left) is displayed next to a RBGE specimen (right).

Future development

Since the support of the Loris image server is stopping at version 2.1 of the image API, we need to adjust the architecture of the current implementation in order to move to the latest version of the IIIF APIs and since we need to redesign our IIIF service, the plan is also to check whether we can build the IIIF service on our JPEG2000 images and serve the data portal with IIIF compliant images.

Deployments

The original goal was to have IIIF deployed at ten institutions within the first year. With the delays associate with Covid-19 this has not been achieved but progress has been made spread over a wide range of institutions. We currently know about seven live installations plus four in development and due to be deployed in summer 2021. There has been general positivity about moving to IIIF within the collections community and there may be other institutions who are implementing the protocol that will come to light in the next phase of the project.

Royal Botanic Garden Edinburgh (E)
- **Status:** IIIF end point in production.

- Example CETAF ID: https://herbarium.bgbm.org/object/B200012401
- Example IIIF Manifest: https://herbarium.bgbm.org/data/iiif/B200012401/manifest.json

Botanic Garden and Botanical Museum Berlin (B)
- **Status:** IIIF end point in production.
- Example CETAF ID: https://herbarium.bgbm.org/object/B200012401
- Example IIIF Manifest: https://herbarium.bgbm.org/data/iiif/B200012401/manifest.json

Museum für Naturkunde Berlin (MfN)
- **Status:** IIIF end point in production.
- Developers actively contributing to IIIF viewer code bases.
- Example CETAF ID: https://portal.museumfuernaturkunde.berlin/detail/179377
- Example IIIF Manifest: https://portal.museumfuernaturkunde.berlin/api/v1/iiif/manifest/179377/manifest.json

Meise Botanic Gardens
- **Status:** IIIF end point in production.
- Example CETAF ID: https://www.botanicalcollections.be/specimen/BR0000022705044
- Example IIIF Manifest: http://iiif-manifest.oxalis.br.fgov.be/specimen/BR0000022705044/manifest

Asociación Jardín Botánico La Laguna (LAGU)
- **Status:** IIIF in production.
- Example CETAF ID: http://lagu.jacq.org/object/PG-03584
- Example IIIF Manifest: http://lagu.jacq.org/iiif/PG-03584

Institute of Botany, Ilia State University (TBI)
- **Status:** IIIF in production.
- Example CETAF ID: http://tbi.jacq.org/object/TBI1038592
- Example IIIF Manifest: http://tbi.jacq.org/iiif/TBI1038592

Herbarium Rita & Eckhard Willing Herbarium
- **Status:** IIIF end point in production.
- Example CETAF ID: https://willing.jacq.org/object/JACQID1184346
- Example IIIF Manifest: http://willing.jacq.org/iiif/JACQID1184346

Finnish Museum of Natural History (Luomus)
- Status: IIIF near production. Image API in place Presentation API to follow.
- Example CETAF ID: http://id.luomus.fi/KN.17856
- Example IIIF Image: https://iiif-laji.rahtiapp.fi/iiif/3/MM.1619624/info.json

University of Leipzig, Herbarium (LZ)
- **Status:** Herbarium LZ is in the process of moving the images to a new IIIF enabled infrastructure which is already quite mature, i.e. json manifest file already in a draft version available.
- Example CETAF ID: https://lz.jacq.org/LZ220043

NHM Vienna (W)
- **Status:** Herbarium W and other departments are restructuring IT Data related operations at the museum, these processes also include visualisation of images; since they are also participating in three Virtual Access projects this is currently a priority and shall be in place in summer 2021.
- Example CETAF ID: https://w.jacq.org/W0100330

University of Vienna, Herbarium (WU)
- **Status:** Move to IIIF capable infrastructure was scheduled for 2020 but has been postponed to 2021. Now expected to be in place by summer 2021.
- Example CETAF ID: https://wu.jacq.org/WU0044029

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Future development

Task 4.3 of Work Package 4 is a relatively small part of the SYNTHESYS+ project. Its aim was to instigate the adoption of IIIF as a new standard in the Natural History community and it appears to have achieved this. IIIF has reached critical mass within the Natural History community and is likely to continue as a key technology.

There are, however, a few things that can be seen to derive directly from the project.

- Each of the case studies presented have outlined their own plans for the further development of their installations. This could be thought of increasing the depth of deployment.
- This implementation guide will facilitate adoption at other institutions by acting as a technical introduction and a link to those who can offer support. The text will be transformed into a wiki (hosted either by CETAF or DiSSCo) so that it becomes a living document and can be updated continuously.
- SYNTHESYS+ is focussed on Europe. Wider adoption outside Europe, initially in North America, would liberate a greater percentage of Natural History material. Representation at the IIIF Annual Conference, June 2022 in Cambridge MA is being investigated and could be combined with promotion of our work to major institutions along the East Coast of the USA.
- Formal adoption of our working practices by the standards organisation TDWG would be a useful step in wider adoption and stability.
- IIIF is likely to become a key building block of the future DiSSCo virtual specimen infrastructure.
- Despite the Covid-19 pandemic, professional relationships have been established between the implementers at different institutions making it easier to initiate future projects.
- Roger Hyam will continue acting as the IIIF Consortium's Ambassador to the Natural History Community.

SYNTHESYS+
Synthesis of Systematic Resources   a DiSSCo project