

On Enabling Fast and Secure Access to Herbarium Specimen Images

 **Jorrit H. Poelen** 

Abstract

Access to Natural History Collections helps researchers to better understand the natural world. Millions of digital images of herbarium specimen are openly available via the Internet. However, using these images in a research project can be cumbersome, because they are hard to access, difficult to cite, and complicated to compile into datasets. Here, we use Preston, a biodiversity data tracker, and rsync, a file-copying tool, to enable fast and secure access to hundreds of thousands of digital herbarium images from the Botanical Research Institute of Texas.

Introduction

This experimental data paper describes a method to facilitate fast and secure use of herbarium specimen records and associated images of the Botanical Research Institute Texas.

Tracking Herbarium Images

Preston ([Elliott 2020](#))([Elliott 2022](#))([Jorrit Poelen 2022](#)) was used to index 825,877 image urls published across three BRIT related to DwC-A records using:

markdown

```
# lists image urls after tracking dwca archives
preston track https://sernecportal.org/portal/content/dwca/VDB_DwC-A.zip\
https://sernecportal.org/portal/content/dwca/NLU_DwC-A.zip\
https://portal.torcherbaria.org/portal/content/dwca/BRIT_DwC-A.zip\
| preston dwc-stream\
| grep URI\
| jq --raw-output '."http://rs.tdwg.org/ac/terms/accessURI" | "http://rs.tdwg.org/ac/terms/thumbna
ilAccessURI" | "http://rs.tdwg.org/ac/terms/goodQualityAccessURI"]'\\
| gzip\
> image-urls.tsv.gz
# list image urls and track them
cat image-urls.tsv.gz | gunzip | xargs -L25 preston track
```

The associated digital images were discovered and retrieved using a server in a data center in Germany on a ~ 1Gb connection in period 2022-06-06 to 2022-07-26.

markdown

```
# calculate start time
$ preston history | head -n1 | preston cat | grep -o -P "2022-[0-9]{2}-[0-9]{2}T.*Z" | sort | uniq | head -n1
2022-06-06T17:02:10.924Z
```

markdown

```
# calculate end time
$ preston history --data-dir $PWD | tail -n1 | preston cat --data-dir $PWD | grep -o -P "2022-[0-9]{2}-[0-9]{2}T.*Z" | sort | uniq | head -n1
2022-07-26T16:47:05.428Z
```

So, it took about 1 month and 20 days to access and retrieve the BRIT images. This translates to a sustained image transfer rate of about 0.2 images/s or 1 image per 5 seconds.

Example Image

An example of a tracked image shown below was extracted using:

markdown

```
# list the first tracked image url
$ preston ls -l tsv\
| grep hasVersion\
| grep -v "well-known"\
| grep -v "zip"\
| head -n1
https://bisque.cyverse.org/image\_service/image/00-Bu6svkTKkNx5hdB8niSokV/resize:1250/format:jpeg
http://purl.org/pav/hasVersion hash://sha256/a3e5efcd9905154afea689e7e3c2756521d5126537811
8a66027c77eba35e06 urn:uuid:063c8cb0-b0b7-469e-a9b8-65e99803ad54

# and retrieve their associated content via their content id
$ preston cat --remote https://linker.bio/hash://sha256/a3e5efcd9905154afea689e7e3c2756521d51265378118a66027c77eba35e06 > BRIT67501.jpg
```



**Fig. 1**

Specimen BRIT67501 *Dicliptera brachiata* Spreng. Collected on 1967-09-28 by R. Kral, Vanderbilt University Herbarium (VDB) CC BY-NC hash://sha256/a3e5efcd9905154afea689e7e3c2756521d51265378118a66027c77eba35e06

with the caption text derived from the associated tracked metadata:

markdown

```
preston ls\
| grep hasVersion\
| grep zip\
| preston dwc-stream\
| grep "https://bisque.cyverse.org/image_service/image/00-Bu6svkTKkNx5hdB8niSokV/resize:1250/format:image/jpeg"\
| jq .
{
  "http://www.w3.org/ns/prov#wasDerivedFrom": "line:zip:hash://sha256/371984ca4566b7b6bc760d0766873b469e12af2d87ce9218f1da888a1b4c3948!/multimedia.csv!L2",
  "http://www.w3.org/1999/02/22-rdf-syntax-ns#type": "http://rs.tdwg.org/ac/terms/Multimedia",
  "http://rs.tdwg.org/dwc/text/coreid": "6816308",
  "http://ns.adobe.com/xap/1.0/rights/Owner": "Vanderbilt University Herbarium (VDB)",
  "http://ns.adobe.com/xap/1.0/MetadataDate": "2018-02-02 11:58:22",
  "http://ns.adobe.com/xap/1.0/rights/WebStatement": "http://creativecommons.org/licenses/by-nc/3.0/",
  "http://purl.org/dc/terms/type": "StillImage",
  "http://rs.tdwg.org/ac/terms/associatedSpecimenReference": "https://sernecportal.org/portal/collections/individual/index.php?occid=6816308",
  "http://rs.tdwg.org/ac/terms/subtype": "Photograph",
  "http://rs.tdwg.org/ac/terms/caption": null,
  "http://rs.tdwg.org/ac/terms/thumbnaillAccessURI": "https://bisque.cyverse.org/image_service/image/00-Bu6svkTKkNx5hdB8niSokV/thumbnail:200,200",
  "http://purl.org/dc/terms/format": "image/jpeg",
  "http://rs.tdwg.org/ac/terms/comments": null,
  "http://rs.tdwg.org/ac/terms/providerManagedID": "urn:uuid:36fd1d6c-3a2b-4cc0-b640-e93c2b400a01",
  "http://rs.tdwg.org/ac/terms/accessURI": "https://bisque.cyverse.org/image_service/image/00-Bu6svkTKkNx5hdB8niSokV/resize:4000/format:image/jpeg",
  "http://rs.tdwg.org/ac/terms/goodQualityAccessURI": "https://bisque.cyverse.org/image_service/image/00-Bu6svkTKkNx5hdB8niSokV/resize:1250/format:image/jpeg",
  "http://purl.org/dc/elements/1.1/creator": null,
  "http://ns.adobe.com/xap/1.0/rights/UsageTerms": "CC BY-NC (Attribution-Non-Commercial)",
  "http://rs.tdwg.org/ac/terms/metadataLanguage": "en",
  "http://purl.org/dc/terms/identifier": "https://bisque.cyverse.org/image_service/image/00-Bu6svkTKkNx5hdB8niSokV/resize:4000/format:image/jpeg",
  "http://purl.org/dc/terms/rights": null
}
```

Image Origins

For this corpus, the following servers were queried for reported image urls:

markdown

```
$ preston ls --data-dir $PWD -l tsv | grep hasVersion | sed 's+https://++g' | cut -f1 | sed 's+/.*/++g' | sort | uniq -c | sort -nr
596759 bisque.cyverse.org
220278 web.corral.tacc.utexas.edu
7537 api.idigbio.org
942 portal.torcherbaria.org
410 storage.idigbio.org
252 sernecportal.org
30 static.inaturalist.org
10 urn:null
4 inaturalist-open-data.s3.amazonaws.com
```

Images Not Found

Preston reports non-responsive URLs as skolemized blanks ([RDF 1.1 Concepts and ...](#)).

Using this labeling of non-responsible image URLs, the following servers produced non-responsive URLs:

markdown

```
$ preston ls -l tsv \
| grep hasVersion \
| grep ".well-known/genid" \
| sed 's+https://++g' \
| cut -f1 \
| sed 's+/.*/++g' \
| sort \
| uniq -c \
| sort -nr
98 web.corral.tacc.utexas.edu
55 bisque.cyverse.org
10 urn:null
3 portal.torcherbaria.org
```

156 image locations appeared to yield no content on tracking them a first time [1 \(when indexing all of ...\)](#) hinting at intermittent access issues.

On retrying the inaccessible content locations, only 33 remained inaccessible [2](#), hinting at possible permanent access issues.

Data Transfer from Germany to US

The BRIT images were originally tracked from Germany on a commercial "off-the-shelf" server.

After receiving blank storage hardware ([2](#)), the BRIT image corpus hash://sha256 /76d40abccfc71bc2cdaf4ea4a6003b9ac49123b27abe9f0d81e233299baf5e94 ([Botanical Research In...](#)) was transferred from Germany to Minnesota, US on 5 Sept 2022 onto a USB 3.0 Seagate Expansion HDD 18TB STKP180000402 PN 3EGAPR-570 connected using a Lenovo T430 running Ubuntu Ubuntu 20.04.5 LTS using Intel® Core™ i5-3320M CPU @ 2.60GHz × 4 and 8GB of memory. The corpus spanned over 900k files / 309GB and was transferred in about 21h (see below for details) via a consumer grade fiber internet connection.



**Fig. 2**

Storage media received by mail on 2022-09-04

A total of 902626 files were received.

markdown

```
# count number of files in data folder
$ find data/ -type f | wc -l
902626
```

Also, the *rsync* logs below captured the transfer statistics, indicating the transfer rate and total volume.

markdown

```
[...]

data/ff/ffffe29becf0e65f3c32f9bb53f18f418fc0e6ff432ab1b2176bad560930be99
    358,999 100%   2.18MB/s   0:00:00 (xfr#902621, to-chk=2/968416)
data/ff/ff/fffffe5eedcebb869f14ecf6cce5b5fceaf29ae363ce833431bba46a19f8eb6c8
    78 100%   0.49kB/s   0:00:00 (xfr#902622, to-chk=1/968416)
data/ff/ff/fffffe8aae693c59e91b94e4de61d7ce035c69c94077ccf158e3d23a0a039216f
    383,141 100%   2.12MB/s   0:00:00 (xfr#902623, to-chk=0/968416)

sent 17,752,067 bytes  received 329,479,912,584 bytes  4,412,629.51 bytes/sec
total size is 329,293,755,413  speedup is 1.00
```

Finally, the *time* program recorded and logged the duration of the transfer.

markdown

```
real 1244m30.854s
user 98m36.885s
sys 55m19.359s
```

Local Verification and Duplication

After receiving the corpus in Minnesota, the content was duplicated locally to a WD Elements 5TB PN WDBU6Y0050BBK-XD. The *rsync* local replication took a little over an hour (~81 minutes), and the Preston-based verification took under 7 hours (322 minutes). The verification checks the local copy and verifies whether the reference content is actually present and has the expected content. Content verification is a computationally heavy operation because hundreds of thousands of files are processed and their cryptographic hashes are re-computed. The verification reported no missing or altered content.

Transfer by USPS

To demonstrate that the image corpus can be transferred without using the internet, the Seagate Expansion HDD 18TB containing the BRIT image corpus copy was labeled and shipped by US Postal Service on 16 Sept 2022.

Conclusion

In period 2022-06/2022-07, images related to three herbarium collections managed by Botanical Research Institute of Texas spanned across primarily two resource locations: (1) bisque.cyverse.org and (2) web.corral.tacc.utexas.edu. The results show that the referenced specimen images were (mostly) successfully transferred (transfer A) in about 2 months at a sustained rate of about 1 image per 5 seconds. A similar transatlantic transfer (transfer B) of this image collection was performed using rsync in 21 hours, showing that transfer B was about 60x more efficient in transferring >800k images than transfer A. Repeating a similar transfer (transfer C) locally took a little over an hour, yielded another order of magnitude in transfer speed improvement, suggesting that the network, not local I/O nor computation, in transfer B was the primary bottleneck compared to transfer C.

Finally, the data was transferred on an external harddisk using the US Postal Service from Minnesota to Texas using Priority Mail (transfer D). Given that this transfer takes less than two months, this transfer will be faster than transfer A.

Discussion

The results suggest that (a) keeping local copy of an image corpus are expected to increase image access speeds by orders of magnitude, (b) BRIT current image access services are optimized for viewing individual images manually, (c) Preston can be used to make identical copies of image corpora of known provenance (or origin) while allowing for verification of the authenticity of the referenced image corpus, and (d) Preston can be used to securely cite a corpus of hundreds of thousands of images in a single line ([Elliott 2022](#)), and, in addition, a QR code can be generated from the citation to further facilitate the access to the image corpus [3](#).



Botanical Research Institute Texas (BRIT): Origins of
BRIT collection records and associated images tracked
in period 2022-06/2022-07.

[has:sha256/76d40abccfc71bc2cdf4ea4a6003b9ac49123b27abe9f0d81e233299baf5e94](https://sha256/76d40abccfc71bc2cdf4ea4a6003b9ac49123b27abe9f0d81e233299baf5e94)

<https://github.com/bio-guoda/preston-brit-2022>

<https://linker.bio/hash://sha256/76d40abccfc71bc2cdf4ea4a6003b9ac49123b27abe9f0d81e233299baf5e94>

Fig. 3

Label with QR Code that uniquely identifies the Botanical Research Institute of Texas image corpus as tracked in period 2022-06/2022-07 ([Botanical Research In...](#))

Label with QR Code that uniquely identifies the Botanical Research Institute Texas image corpus as accessed in period 2022-06/2022-07 ([Botanical Research In...](#))

Over the last decades, millions of dollars have been invested in digitizing existing collections. Now, readily available methods, like those implemented by rsync and Preston, may help unleash the full potential of this ever growing corpus of digital resources by increasing processing speeds of

verifiable, and clonable, image corpora.

Appendix A

Data

```

https://bisque.cyverse.org/image_service/image/00-fXkw8KPeArtBjNrPHTvTU/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-cXkjNdUW9rKCE8etGzpHtg/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-intt3JyJUMbaF3FBJztkhc/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-d3bwMyyiXEQHApGbtd6LxF/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-aGd7xZ2uPa9Kbsfr8CepBm/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-RjMY6Zz1s3JdapmTuuf6L/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-C4CNLCZD46aJZmcxx4rm2i/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-3TJvfeyG9D8wtKStkza8AG/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-F7jtcCZ9oBA3j2YnwbmKrH/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-g96HN5fQsJnEoBLbhgw8Le/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-iyKdXjKoQtGx9iZxeEQDM/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-6GjTcou77eDxdbcixkGt9c/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-tX6XLpXivgF6t9jkesZ3F/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-CzChz3A6abzTwB9zCeRZCi/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-QoChePYv8BYXJ3bYDwadR/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-9otLzbWxT9MyeCGqJu9Fg8/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-ie3faMpL5fmZZGmW6dfyyf?resize=1250&format=jpeg
https://bisque.cyverse.org/image_service/image/00-PSmXxi7jyuwuXnFbmfCAF2e?resize=1250&format=jpeg
https://bisque.cyverse.org/image_service/image/00-GYe8bJ3z7KozDsJqbzfVVZ?resize=1250&format=jpeg
https://bisque.cyverse.org/image_service/image/00-T88aXALn5zsWPhaP6dvEKd/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-gdGPD7Xmo9NoqSDKXszgN/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-N4VHTti4mToxwCcJXHHQnB/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-iX4e3CcK6qDU4npjabyE39/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-MAGIxLashpnatT3B9DDlb/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-jt29JHUMYHVZBdMwX8YEjf/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-cGNuk7rjCFQJwRwkEre4zg/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-2wXBZEQdEsFwamBV2SLfpZ/resize:1250/format:jpeg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0509000/BRIT509186_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0557000/BRIT557009_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0502000/BRIT502367_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0502000/BRIT502116_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0502000/BRIT502415_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0502000/BRIT502258_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0502000/BRIT502460_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0502000/BRIT502086_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0545000/BRIT545461_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0547000/BRIT547289_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0536000/BRIT536480_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0537000/BRIT537103_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0240000/BRIT240966_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0537000/BRIT537135_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0537000/BRIT537131_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0539000/BRIT539156_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0539000/BRIT539158_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0539000/BRIT539144_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0539000/BRIT539136_med.jpg
https://web.corral.tacc.utexas.edu/torch/BRIT/BRIT0539000/BRIT539143_med.ina

```

Table 1

156 image URLs failing to produce content on first attempt

Appendix B

Data

```

https://bisque.cyverse.org/image_service/image/00-7J9FqXFGUzAyrVZbgJJ0GG/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-anTuWfwkPTuFCGs40VpgT/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-bd6zjsQ5MUErQZS9M5Sr8M/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-bedLvssypaWBZSXxH7xkkc/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-bP7yMwfUoJqkHLXgVxpmb8/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-dDfCUqfDWiKywrvrcXaEkWY/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-dguyqrpa3MhC4mFQAvffiE/resize:1250/format:jpeg

```

https://bisque.cyverse.org/image_service/image/00-drdU6yfV2iMHEScNCCnauC/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-fzaczeURipNgfB5ATsN9jX/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-gdGPD7Xmo9NoqSDKXsgzN/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-iX4e3CcK6qDU4npjabyE39/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-jt29JHUMYHVZBdMwX8YEjf/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-JTMst2xqjGtEkRj2XTUnf8/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-K6MzoZ5CzdCjkYNrToQvT/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-KFQVR865F2tCnmFuFE2Sfc/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-Kknpn4havinGzqosXciy84/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-kTVY9mVbNbMmJ9m6sEa6ei/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-MAGixLashpnatT3B9DDLb/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-mDAzNumFjZw6UcTadscLnF/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-N4VHTti4mToXwCcJXHHQnB/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-NNbUnwSApdKpw88ja730/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-NseahVLc4aigczTwhpx38/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-Q8wQTFujfbGKFxHQRjfSca/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-rB3x6s6GiQdf3zM39XWbte/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-Va4gmxvFrMyhNGahaDBrZe/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-Vg77D6Crctp2M3bM5q2Wbp/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-wmVfuTzpyNtMq1GZrbp2GZ/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-wQhG7Kwjx7bfibi3xgnDxG/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-Y4gyWqVBAWtjQxvijXmXxC/resize:1250/format:jpeg
https://bisque.cyverse.org/image_service/image/00-zEx63i64ZvuGotD3whiFfT/resize:1250/format:jpeg
https://portal.torcherbaria.org/imglib/seinet/torch/BRIT/202006/field_madder-6270273_1593287703.jpg
https://portal.torcherbaria.org/imglib/seinet/torch/BRIT/202007/scf_35-2_1595371669.jpg
https://portal.torcherbaria.org/imglib/seinet/torch/BRIT/202010/IMG_0846_1601579155.jpg

Table 2

33 image URLs failing to reproduce content after second attempt.

References

Show all references in article bibliography

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3. Michael Elliott Jorrit Poelen. bio-guoda/preston: (0.3.9). Zenodo (2022). [Link](#) [Edit](#)
4. RDF 1.1 Concepts and Abstract Syntax. [Link](#) [Edit](#)
5. when indexing all of BRIT during June/July 2022 some 156 images failed to resolve, and 33 remain inaccessible after single retry · Issue #1 · bio-guoda/preston-brit-2022. [Link](#) [Edit](#)
6. Botanical Research Institute Texas (BRIT): Origins of BRIT collection records and associated images tracked in period 2022-06/2022-07. hash://sha256/76d40abccfc71bc2cdaf4ea4a6003b9ac49123b27abe9f0d81e233299baf5e94 https://github.com/bio-guoda/preston-brit-2022 https://linker.bio/hash://sha256/76d40abccfc71bc2cdaf4ea4a6003b9ac49123b27abe9f0d81e233299baf5e94. [Edit](#)