Designing Knowledge Bases for Humanities Research: challenges and approaches

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Challenges of interdisciplinary research

- requires gradual development of a common “language of discourse” between researchers from different disciplines:
  - often, a term has different meanings in different disciplines e.g. “data”, “ontology”, “design”, “implementation”

- requires sensitivity to the research challenges and the ways of working of the other disciplines

- there is typically a lack of well-defined software requirements at the outset of the research project:
  - Identifying initial outline requirements on the basis of which to begin to research and design initial prototype software is a necessary first step
Challenges of interdisciplinary research

- the research typically then progresses in an *iterative and collaborative* fashion, comprising successive cycles of
  - requirements elicitation
  - research
  - design
  - implementation
  - trialling

in collaboration with groups of domain experts and users/user stakeholders
Challenges of developing specialised KBs to support Humanities research

• lack of existing ontologies or datasets on which to base the design of the KB, due to the specialisation of the domain
• the development of conceptualisations and knowledge models by the domain experts is part of the research itself
• incremental collection and collation of data from diverse sources; additional data sources become known/available during the course of the research project
• incremental development of the domain experts’ conceptual model in tandem with the incremental collection of the data
• sometimes uncertainty, controversy and multiple viewpoints from the range of domain expert stakeholders, that need to be resolved
Challenges of developing specialised KBs to support Humanities research

- incompleteness, imprecision and contradictions in the data; data quality improves during the course of the research
- difficulty in specifying requirements for facilities to Search, Visualise and Analyse the data while the conceptual model development and data collection are still in progress
- this cannot begin until the conceptual model and data collection have progressed to some extent; the requirements continue to evolve as long as the conceptual model and data continue to evolve
- gradual collection of diverse data and gradual development of understanding points to the need for adopting semantic technologies and iterative, agile development
Example 1 – Weaving Communities of Practice (AHRC, 2009-2013)

- This was a pilot project to create a Knowledge Base of Andean Weaving textiles history and practice, with the aim of contributing to curatorial practice and heritage policy (see http://www.weavingcommunities.org)

- The research team gathered data on activities, instruments, resources, peoples, places, and knowledge involved in the production of textiles, relating to over 700 textile samples

- A major part of the project was the modelling and representation of the knowledge of domain experts, and information about the textile objects themselves, in the form of an **OWL ontology**

- Followed by the development of a suite of **search facilities** to be supported by the ontology
Weaving Communities of Practice

• The project was the first to undertake ontological modelling for the domain of Andean Weaving

• It brought together a multidisciplinary team of ethnographers, linguists, archaeologists, museum curators, weavers, art historians, cultural geographers and computer scientists with the aim of creating the Knowledge Base

• The project took into account weaving terminology found in the Andean languages of Aymara and Quechua, obtained by a working group of Andean linguists and native language speakers and weavers
Weaving Communities of Practice

• The domain experts gathered information relating to over 700 textile samples, ranging from the Archaeological period (1800 BC – 1535 AD) to the Historical (1535 – 1900 AD) and Contemporary (1900 – present) periods, with production sites across Bolivia, Chile, Peru

• Primary data was gathered in the Aymara, Quechua, Spanish and English languages

• The outcome of the data gathering phase ultimately consisted of approximately 30 different spreadsheets, containing about 1000 rows in total
Weaving Communities of Practice

• Data was collected in collaboration with several museums holding extensive Andean textile collections
• Small weaving models of techniques found in museum collections were also prepared by the project’s textile team
• The project domain experts also visited communities in the Andes in places such as Qaqachaka, Bolivar, Sacaca and Mollo in Bolivia, Puno, Pitumarca and Chawaytiri in Peru, and Colchane and Pisigacarpa in Northern Chile, interviewing active weavers, observing their techniques and styles, and examining their weavings
Research Challenges

• The information relating to Andean textiles is *complex* and even for a domain expert it is far from straightforward to model this domain knowledge.

• The knowledge of domain experts is also often *incomplete*, due to the fact that Andean textile collections are scattered around the globe, making it hard for individual researchers to gain a full perspective.

• Different experts may also *disagree* on how to model certain aspects of the knowledge related to textiles.

• During several workshops and visits, interviews and informal meetings were held with groups of domain experts to *discuss and affirm the validity of the data* being gathered.
Research Challenges

• Both the knowledge model and the data gathered for the project were **rapidly evolving**, particularly in the early stages of the research.

• This meant that the requirements for the search facilities that the KB would support could not be elicited until the KB had itself reached a reasonably stable state.

• Other challenges encountered included:
  
  – **cognitive mismatch** between the domain experts and computer scientists: different groups understanding and describing the same real-world concept in different ways.
  
  – **modelling imprecision**: occasionally the real world is just too complex to be mapped precisely into a computer model!
Research Approach

• The project opted to develop an ontology rather than a relational database/other structured database to represent the domain knowledge and the data being gathered:
  – An ontology gives more flexibility in integrating new domain knowledge and data as this becomes available and evolves
  – An added advantage is that formal reasoning can be applied to validate the evolving knowledge model

• An iterative approach was adopted in which domain experts participated fully in the requirements, design and evaluation aspects of the software development throughout the project
Methodology for Developing the Ontology

- In the first phase of the project (about 21 months) the domain experts gathered and analysed large amount of data, most of it recorded in spreadsheet form.

- In the next phase, the lead domain expert modelled the domain using **yED graphs**. Using this intermediate visual form (rather than an ontology representation directly) provided greater ease, for the non-computer scientists on the project, of understanding and correcting the complex inter-relationships between concepts.

- The yED graphs were then transformed into OWL Lite by writing XQuery-based scripts to generate the T-Box of the ontology (in the form of RDF/XML files).
Methodology for Developing the Ontology

- The A-Box of the ontology was created directly from the spreadsheet data, using a three-step approach:
  - Transforming the spreadsheet data into an equivalent XML format, using XQuery scripts
  - Transforming this initial XML format into an intermediate XML format, using a set of ‘interpretation templates’ that were manually derived from the yED diagrams
  - Transforming the XML intermediate format into RDF.

- XQuery scripts were written to validate the outputs of each phase with respect to those from the previous phases.

- Formal reasoning was also applied to validate aspects of the ontology, using the HermitT reasoner, e.g. to verify that all the classes were non-empty.
Overview of the Ontology Development Process
Methodology for Developing the Search Facilities

• Following the production of the final version of the ontology (at month 39 of the project), the last phase of the project involved the development of the Search Facilities

• Two major Use Cases were identified for the Search Facilities:
  i. the need for the user to be able to Browse through the ontology by navigating through its classification hierarchies;
  ii. the need for the system to support a set of Queries each targeting a specific Research Question that a domain expert may have.

• Powerpoint mock-ups drawn up by the lead domain expert were used as a starting point for designing the user interface
Methodology for Developing the Search Facilities

- The set of queries relating to Use Case (ii) were iteratively developed in collaboration with all the domain experts.
- Although we first implemented individually each of the queries identified for Use Case (ii), it subsequently became apparent that a more general querying facility would be able to support all of these queries, and more.
- The technical team therefore designed a new, generic, querying facility that encompasses this more general functionality.
Sources of textile samples clockwise from top left: British Museum [Am1954,05.448]; British Museum [Am1907,0727.4]; Museo Nacional de Arqueologia, La Paz [661]; Victoria and Albert Museum [CIRC.415-1932]; Victoria and Albert Museum [T.60-1965]; Museo Nacional de Etnografia y Folklore, La Paz [19351]. Photographs copyright of the Instituto de Lengua y Cultura Aymara (ILCA), La Paz.
Product: Headband fragment
Period: Early Intermediate (200 BC-600 AD)
Repository: Victoria and Albert Museum (website), museum ID: T.60-1965
Production site: Paracas, Peru, South coast
Find site: Paracas (Necrópolis), Peru, South coast
Style: Paracas (Necropolis)
Motif: Twisted threads
Technique: Transposed warp technique with multiple interlaced wefts selected by group
Structure: Transposed warp structure with multiple interlaced wefts, warped in 1 layer
Culture: Paracas
Composition: Band
Component: Structural component
Thread 1: Warp thread, material: Camelid fibre, type of Torsion: Regular monochrome SZZ, colour of the thread strands: Strands of the same colour, thickness: Very thin: less than 30, direction of torsion: S, torsion of thread: Strong (30°-45°)
Thread 2: Weft thread, material: Camelid fibre, type of Torsion: Regular monochrome SZZ, colour of the thread strands: Strands of the same colour, thickness: Very thin: less than 30, direction of torsion: S, torsion of thread: Strong (30°-45°)
Fabric: Transposed warp with multiple interlaced wefts
Colour: Blue    | Bluish violet    | Green    | Reddish brown
        | Reddish violet
Number of colour layers: 1
Contrast: None
Finish:
Motif attribute:
Scene:
Sequence:
Symmetry:
Size: Unknown
Usage:
Direction of warp:

Output type: Select the type of search result you are looking for from the left-hand menu

Input filter:
- Period: Early Intermediate (200 BC-600 AD)
- Colour: Blue

Select one output type

Select one or more input filters

- Colour
  - Black
  - Blue
  - Bluish violet
Output type: **Find site**

Input filter:

- **Period:** Early Intermediate (200 BC-600 AD)
- **Colour:** Blue

7 results

- **Bolivia** product details
- **Central coast** product details
- **Nasca** product details
Methodology for Developing the Search Facilities – User Evaluation

• We recruited 25 volunteers via our networks of contacts with museums, researchers and textile practitioners to evaluate the usability and usefulness of the system (*formative evaluation*)

• None of these people had had any prior involvement with the project. We held several identically structured evaluation sessions each attended by a subset of the participants

• Several days before each session, participants were sent an information sheet describing the aims and format of the session, and a consent form to sign and return. They were also sent the URL of the project website, so as to be able to gain some background into the aims of the project if they so wished
Methodology for Developing the Search Facilities – User Evaluation

• A member of the research team started the session by giving an overview of the aims and objectives of the project, and illustrated the Browsing and Search facilities on a projector.

• Participants were asked to undertake two Browsing tasks and three Search tasks, to record their answers to each task, and to answer a small set of questions regarding the ease-of-use of the Browsing and Search facilities. Participants were invited to add further comments if they wished. At the end of the five tasks, participants were also invited to answer a set of more general questions about the system’s usability and usefulness.

• Generally, the evaluation participants’ responses to the system were positive; they led to several improvements being made to the user interface and the overall system for its final version.
References


• See also full list of publications at http://www.weavingcommunities.org/about/publications.html
Example 2 – Mapping Museums: the history and geography of the UK independent sector 1960-2020 (AHRC, 2016-2020)

• This project is aiming to provide the first evidence-based history of the development of the UK’s independent museums sector and the links to wider cultural, social, and political concerns (see http://blogs.bbk.ac.uk/mapping-museums/)

• As such, it aims to contribute to scholarly understanding of British culture, be useful for policy makers and arts funders, and also be of interest to the general public
Mapping Museums

• During the first 18 months of the project, the research team has gathered and codified data on some 4000 UK museums.

• A major part of the project to date has been the modelling and representation of the knowledge of domain experts in the form of an RDFS ontology.

• Combined with, in parallel, the design and development of a suite of **Browse, Search** and **Visualisation facilities** to be supported by the KB.
Mapping Museums

• The project is the first to produce an authoritative database of museums opening and closing during a period of rapid expansion and change in the sector

• Ongoing research using the database is seeking to identify trends in the development of independent museums:
  – when museums opened
  – if there is a link between where/when they opened and their subject matter
  – if there are areas where few museums opened or survived
  – and if these patterns correlate to other broader cultural or social factors
Data Collection

- There were no directly usable digital datasets, and all of the data had to be entered manually into an evolving "master" spreadsheet, plus additional auxiliary s/sheets.
- OCR techniques were also used to process photographs from the Association of Independent Museums archive (housed at the University of Leicester).
- The Digest of Museum Statistics (DOMUS), 1994-1999, was used as the starting point (around 1,800 museums).
- Additional contemporary and historical datasets from various organisations (e.g., Arts Council England, Museums and Galleries Scotland, Association for Independent Museums) were then incorporated.
- Use of online resources such as museums' websites and Wikipedia resulted in a wider spread of entities that are considered as being "museums" by the public.
Data Collection

• To reduce missing, uncertain & inconsistent data, used online search engines, digital resources (BBC 1986 Domesday project, TripAdvisor), physical resources (Hudson and Nicholls 1985 Museum Directory), historic guidebooks, consulted subject specialists (Museums Development Network), made hundreds of telephone calls, conducted email and twitter correspondence

• The outcome of the data collection phase (at 15 Months) was a main excel s/sheet comprising over 50 items of data relating to around 4000 museums
  – also two additional s/sheets of historical data relating to changes in Governance Status and Visitor Numbers over time
Research Challenges

• Incomplete knowledge of the independent museums sector, hence evolution of knowledge as the project progresses
• Existing data gathered by the Museums Association and regional and national funding bodies is patchy and does not encompass smaller venues
• Incompleteness of the data that was being collected:
  – missing data
  – contradictory data
  – imprecision about the year of a museum opening/closing:
    • sometimes best-effort estimates were needed, in the form of a pair (earliest possible year, latest possible year)
    • this in turn led to the need to support of Modal logic operators for comparing dates (Definitely/Possibly)
Research Challenges

What is a museum? This is clear-cut for established institutions, but not always so for small, local, independent institutions

- could be instead be “a zoo, a library, a café”
- in many instances case-by-case decisions needed to be made for ‘grey areas’ e.g. “visitor centres, historic windmills, church treasuries”
- criteria for inclusion adopted were broader than existing “official” definitions to ensure grassroots museum ventures are fully captured
Research Challenges

• Classification of museum Subject Matter:
  – the existing DOMUS subject classification (1998) focusses on academic disciplines, so not able to capture the full richness of independent museums
  – the project’s domain experts have developed a new classification scheme that adheres more closely to the reality of independent museums
  – this has been validated by members of the Museums Development Network and finalised with their feedback
Research Approach

• Evident from the outset that the gradual collection of diverse data and gradual development of understanding about the required functionality of the KB would require an iterative, agile methodology to be adopted

• Also pointed to the need to adopt semantic technologies in order to develop the KB and search facilities:
  – the different relationships between entities can be described in fine detail
  – both the conceptual model and the data can be extended with new triples as new knowledge/data accrue
  – possible to integrate the evolving MM ontology with other existing taxonomies, e.g. as relating to geographical regions (ONS) and subject classification (DOMUS)
Example working document:
Administrative Areas (version 5)

Notes:
We will record in our database two names for each administrative area: (i) the ONS name, (ii) the “typed ONS name”, which in most instances (see below for the exceptions) adds the type of admin area to its ONS name within round brackets. It is the “typed ONS name” that will appear in the text auto-completion list within the Search Facility.

- There are no instances of the class Administrative Area – it is there as a “placeholder” in the conceptual model.
- There are four instances of the class Country, with ONS names “England”, “Scotland”, “Northern Island”, “Wales”. Their “typed ONS name” will be the same (i.e. without “(Country)” appended).
- Only England contains instances of English Region.
- Only Northern Island contains instances of NI Loc Gov District [11 such instances]
- Only Scotland contains instances of Scottish Council Area [32 such instances]
- Only Wales contains instances of Welsh UA [22 such instances]
- There is only one instance of Greater London. Its “typed ONS name” is “Greater London” (not “Greater London (Greater London)”).
- “Greater London” is connected to “England”.
- There is only one instance of City of London, contained in Greater London. Its “typed ONS name” is “City of London”. 

Conceptual Model for Administrative Area, showing the Classes and the “contains” relationship (->)

- English Region
- NI Loc Gov District
- Scottish Council Area
- Welsh UA
- English County
- English UA
- Greater London
- London Borough
- City of London
- English District or Borough
Research Approach

- Co-developing **graphical conceptual models** from the outset of the project has allowed us to gradually develop a common understanding across the whole team of the information that the KB will contain.

- These were initially hand-drawn diagrams on paper, whiteboards, powerpoint.

- And were subsequently modelled using the yED tool:
  - the format of the main Museums data spreadsheet was kept “in synch” with this evolving conceptual model.
  - most of the graphical specification was automatically extracted from the metadata header of the Museums data spreadsheet (using Python).
  - additional modelling was added manually as required, e.g. for historical attributes (changes in Governance status, visitor numbers data) and the ONS administrative area hierarchy.
Zooming in on: Governance
Data sources
Visitor Numbers Historical Data
ONS Administrative Areas
Methodology for Developing the KB

- Initial data collection and initial conceptual model development (6 months)
- Development of first version of the RDF/S store (9 months):
  - an RDFS template is created from the graphML file exported by yED (using Python)
  - the RDFS template is then combined with the s/sheet data (converted to CVS) to generate the triples in N3 (Python)
  - this is then converted to RDF/XML, allowing automatic checking of the syntactic correctness of the triples to be loaded to the triple store
- Iterative extension of the RDF/S store (20 months), including extension with temporal attributes, ONS Administrative Areas, and additional ONS datasets
Methodology for Developing the Web Application over the KB

- First prototypes of Browse and Search at 12 months; and Visualisations at 15 months; iterative development still ongoing
  - the conceptual model and the data being gathered were rapidly evolving, so requirements for the search facilities that the KB would support could not be elicited until the KB had itself reached a reasonably stable state
- Project team members again began by producing hand-drawn sketches on paper and whiteboards
- Browse and Search have been inspired by Browse and Search from “Weaving Communities of Practice”
- Visualisations are more challenging, especially as relating to the spatio-temporal data – has led to expansion of the project team at month 15 with an expert in GIS
Web Application Architecture

Client Application
(Javascript, Bootstrap3, Leaflet, G2, Bokeh, Openstreetmap)

Web Server – Apache/WSGI
(Python – Flask framework, SPARQL wrapper, Bootstrap3, Bokeh)

Database Server (Virtuoso)
Browse
Browse
<table>
<thead>
<tr>
<th>Museum Name</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aberystwyth Ceramics Gallery</td>
<td>Arts-Ceramics</td>
</tr>
<tr>
<td>Adderstone Art Gallery</td>
<td>Arts-Fine and decorative arts</td>
</tr>
<tr>
<td>Bacup Natural History Society and Museum</td>
<td>Mixed</td>
</tr>
<tr>
<td>Banff Museum</td>
<td>Local Histories</td>
</tr>
<tr>
<td>Blackburn Museum and Art Gallery</td>
<td>Mixed</td>
</tr>
<tr>
<td>Booth Museum of Natural History</td>
<td>Natural_world-Mixed</td>
</tr>
<tr>
<td>Botanic Gardens Museum</td>
<td>Mixed</td>
</tr>
<tr>
<td>Brighton Museum and Art Gallery</td>
<td>Mixed</td>
</tr>
<tr>
<td>Bristol Museum and Art Gallery</td>
<td>Mixed</td>
</tr>
<tr>
<td>Burns Monument Centre</td>
<td>Personality-Literary</td>
</tr>
<tr>
<td>Charterhouse School Museum</td>
<td>Mixed</td>
</tr>
<tr>
<td>Cheltenham College Museum</td>
<td>Mixed</td>
</tr>
<tr>
<td>Derby Museum and Art Gallery</td>
<td>Mixed</td>
</tr>
<tr>
<td>Name of museum</td>
<td>ABERYSTWYTH CERAMICS GALLERY</td>
</tr>
<tr>
<td>---------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Address line 1</td>
<td>Aberystwyth Arts Centre</td>
</tr>
<tr>
<td>Address line 2</td>
<td>Penglais</td>
</tr>
<tr>
<td>Town or City</td>
<td>Aberystwyth</td>
</tr>
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<tr>
<td>Accreditation</td>
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</tr>
<tr>
<td>Governance</td>
<td>University</td>
</tr>
<tr>
<td>Visitor Numbers Data</td>
<td>400000 at 1995</td>
</tr>
<tr>
<td>Visitor Numbers Data</td>
<td>400000 at 1997</td>
</tr>
<tr>
<td>Visitor Numbers Data</td>
<td>0 at 1895</td>
</tr>
<tr>
<td>Visitor Numbers Data</td>
<td>0 at 1994</td>
</tr>
<tr>
<td>Classification 2015</td>
<td>Arts Ceramics</td>
</tr>
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Browse
Browse
Browse
Browse
Search
<table>
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<th>NameOfMuseum</th>
<th>County</th>
<th>Classification 2018</th>
<th>Year opened</th>
<th>Year closed</th>
<th>Governance</th>
<th>Admin Area</th>
<th>Accreditation</th>
<th>Classification 1888</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aberdeen Art Gallery</td>
<td></td>
<td>Arts and decorative arts</td>
<td>1884</td>
<td>Still open</td>
<td>State: Local Authority</td>
<td>Scottish_Council_Area</td>
<td>Accredited</td>
<td>mixed collection</td>
</tr>
<tr>
<td>Aberdeen Maritime Museum</td>
<td></td>
<td>Sea and seafaring: Mixed</td>
<td>1984</td>
<td>Still open</td>
<td>State: Local Authority</td>
<td>Scottish_Council_Area</td>
<td>Accredited</td>
<td>maritime</td>
</tr>
<tr>
<td>Aberdeen Science Centre</td>
<td>Aberdeen City</td>
<td>Science and technology: Other</td>
<td>1988</td>
<td>Still open</td>
<td>Independent: Trust or Foundation</td>
<td>Scottish_Council_Area</td>
<td>Unaccredited</td>
<td>science and industry</td>
</tr>
<tr>
<td>Anatomy Museum, University of Aberdeen</td>
<td></td>
<td>Medicine and health: Other</td>
<td>1860</td>
<td>Still open</td>
<td>University</td>
<td>Scottish_Council_Area</td>
<td>Accredited</td>
<td></td>
</tr>
<tr>
<td>Gordon Highlanders Museum</td>
<td>Aberdeen</td>
<td>War and conflict: Regiment</td>
<td>1936</td>
<td>Still open</td>
<td>Independent: Trust or Foundation</td>
<td>Scottish_Council_Area</td>
<td>Accredited</td>
<td>military</td>
</tr>
<tr>
<td>Herbarium, University of Aberdeen</td>
<td></td>
<td>Natural world: Herbaria and gardening</td>
<td>1860</td>
<td>Still open</td>
<td>University</td>
<td>Scottish_Council_Area</td>
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<td></td>
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<td>James Duns House</td>
<td>City of Aberdeen</td>
<td>Local Histories</td>
<td>1975</td>
<td>2001</td>
<td>State: Local Authority</td>
<td>Scottish_Council_Area</td>
<td>Unaccredited</td>
<td></td>
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<td>Marischal Museum, University of Aberdeen</td>
<td></td>
<td>Mixed</td>
<td>1907</td>
<td>2008</td>
<td>University</td>
<td>Scottish_Council_Area</td>
<td>Accredited</td>
<td></td>
</tr>
<tr>
<td>Provost Skene's House</td>
<td>City of Aberdeen</td>
<td>Buildings: House: Large</td>
<td>1953</td>
<td>Still open</td>
<td>State: Local Authority</td>
<td>Scottish_Council_Area</td>
<td>Accredited</td>
<td>decorative and applied arts</td>
</tr>
<tr>
<td>Robert Gordon University</td>
<td></td>
<td>Mixed</td>
<td>[1950-2017]</td>
<td>Still open</td>
<td>University</td>
<td>Scottish_Council_Area</td>
<td>Accredited</td>
<td></td>
</tr>
<tr>
<td>St Peter's Heritage Centre</td>
<td></td>
<td>Local Histories</td>
<td>1999</td>
<td>Still open</td>
<td>Independent: Trust or Foundation</td>
<td>Scottish_Council_Area</td>
<td>Unaccredited</td>
<td></td>
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</tbody>
</table>
Visualise
Visualise
Visualise
Visualise
Visualise
Visualise
Visualise
Ongoing work

- Formative evaluation with user stakeholders, summer 2018
- Finalising the Web application, autumn 2018
- Development of full project website, 2019
- Support of humanities scholars’ ongoing research, 2018-2020; e.g. for a first analysis of Museum Closures 1960-2017 see http://blogs.bbk.ac.uk/mapping-museums/2018/02/23/museum-closure-pre-findings/
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