ICOM-CC
19th Triennial Conference
2021 Beijing

SCIENTIFIC RESEARCH

The opportunities of a global, shared research infrastructure for the conservation community

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Keywords
heritage science, research infrastructure, cross-disciplinarity, access, outreach

Abstract
Heritage science requires a combination of knowledge from a large number of diverse disciplines, transcending boundaries in a way that is often difficult, or even impossible, to achieve by individuals or small research groups. This paper reports on the latest developments in the advancement of a shared global research infrastructure representing an advanced research community that has been systematically developing since 1999, providing access to analytical facilities, research and networking. Most users of this network have been involved in scientific research. This current initiative is reaching out to all heritage sectors to ensure that the research being carried out is appropriate, necessary, relevant and accessible to all heritage professionals. This paper is a first step in this outreach to the conservation community in its widest sense. Our goal is to set up a dialogue in which common aims are identified and common solutions sought, to benefit all branches of heritage science.

INTRODUCTION

Heritage science is the interdisciplinary domain of scientific study of heritage. It draws on diverse humanities, sciences and engineering disciplines and focusses on enhancing the understanding, care and sustainable use of heritage to enrich people's lives, both today and in the future. Heritage science is an umbrella term encompassing all forms of enquiry, not only scientific, into human works and the combined works of nature and humans that are of value to people.

The solving of significant research problems requires the broad sharing of data, expertise and equipment as well as networking. Sharing the best resources available enables top-level research in both specific and cross-cutting scientific and heritage domains, for the benefit of all stakeholders.

This paper reports on the latest developments in the advancement of a shared global research infrastructure for heritage science. It outlines the challenges and opportunities for the development of a research strategy shared with, and informed by, the conservation community. Among its aims are the opening up of so far unexplored, or underexplored, areas of studies and research that will benefit heritage in its widest sense. This is an exciting development and an opportunity to undertake previously unattainable research.

MISSION

Research infrastructures (RIs) are facilities, resources or services of a unique nature, identified by research communities to conduct top-level research activities. The European Research Infrastructure for Heritage Science (E-RIHS) is one such RI currently being developed. The core mission of E-RIHS is to deliver integrated access to expertise, data and technologies through a standardised approach, to integrate leading resources and to create an organisation with a clear identity and a strong cohesive role within the global heritage science community. Its main objectives are heritage interpretation, preservation, documentation and management based on advanced sharing across disciplines.

New instruments, new protocols and new techniques have a decisive impact on heritage science research, enabling an improved understanding of heritage objects and sites. E-RIHS will stimulate innovation in large-scale instrumentation, portable technologies and data science, and will

foster multi-modal approaches using coupled techniques. At the forefront, digital technologies are rapidly expanding and opening uncharted research territories. An exciting example is the rise of new imaging methods that allow the extreme complexity of heterogeneous, chemically complex and multi-scale heritage materials to be understood.

Through cross-disciplinary access to four principal platforms (FIXLAB, MOLAB, ARCHLAB, DIGILAB), E-RIHS will support object-focussed case studies as well as stimulate and drive large-scale collaborative projects. E-RIHS will also promote best practices and develop or advance methods designed to respond to the specific needs of heritage assets, whether material or digital. The core values pervading all E-RIHS activities are set out as:

(i) Competencies first: Skills are considered as central to success.

(ii) Cross-disciplinarity: E-RIHS will foster a culture of exchange and equitable cooperation between disciplines (experimental sciences, conservation and conservation science, arts, humanities and social sciences, or digital sciences).

(iii) Co-creation: It will build on a paradigm that balances contributions from all participants in research, partners and stakeholders alike.

(iv) Engagement: The promotion of the public-facing nature of heritage science research is a key consideration.

(v) Excellence: E-RIHS will promote excellence by implementing a quality management system, independent selection of outstanding projects and data policies guided by FAIR principles.

(vi) Interoperability: Data and processes will be managed to optimise access, develop intelligent instruments and establish common procedures.

(vii) Innovation: E-RIHS will stimulate innovation on all levels of operation, from the development of new research methodologies and tools to improved access provision.

(viii) International recognition: The operation of E-RIHS will be on a global level.

(ix) Ethics: E-RIHS will promote heritage values and encourage responsible research and innovation.

(x) Quality: Excellent user experience will be sought.

SYSTEM OF LABS

The externally facing image of E-RIHS will be defined by its centrally managed offer of services to the heritage science research community, through four integrated access platforms:

(i) E-RIHS FIXLAB: large-scale and medium-scale fixed facilities, e.g. particle accelerators and synchrotrons, neutron and laser sources and other essentially immovable research facilities including the associated unique expertise;

(ii) E-RIHS MOLAB: access to a comprehensive selection of mobile analytical instrumentation for non-invasive measurements on objects, buildings and sites, allowing the implementation of complex multi-technique diagnostic projects for in situ investigations;

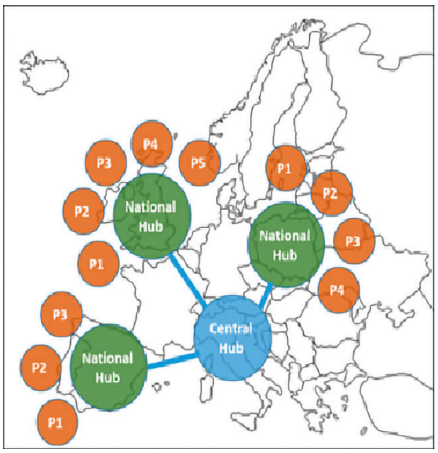

Figure 1. The two-level architecture of E-RIHS

(iii) E-RIHS ARCHLAB: access to physical heritage science collections, such as technical images, samples and reference materials, analytical data and conservation documentation, as stored in museums, galleries and research institutions;

(iv) E-RIHS DIGILAB: online access to data concerning heritage, with the aim of making it findable, accessible, interoperable and re-usable, based on the FAIR principles. This includes and enables access to searchable registries of datasets, reference collections, thesauri, ontologies, etc., and supports data interoperability through the creation of shared knowledge organisation systems.

BACKGROUND

E-RIHS represents an advanced research community that has been systematically developing since 1999, when the LabS TECH (Laboratories on Science and Technology for the Conservation of European Cultural Heritage) consortium was developed and funded (EU FP5 programme). Following its successful completion, it was followed by Eu-ARTECH, which developed along three lines: access to analytical facilities, research and networking. These were further developed and complemented by additional major EU-funded integration research and infrastructural projects such as CHARISMA and IPERION CH in conservation science and ARIADNE in digital archaeology, as well as clusters PARTHENOS[1] and SSHOC[2].

E-RIHS is building on this experience and is based on the proposal submitted to ESFRI (the European Strategy Forum on Research Infrastructures) to establish a permanent European research infrastructure to support the heritage science community, and to the GSO[3] in 2014 to be considered among the RIs with global scope. ESFRI approval highlighted the relevance of E-RIHS to the European Research Area (ERA), and E-RIHS was incorporated into the ESFRI Roadmap in 2016, then the only research infrastructure project in the Social and Cultural Innovation domain. Furthermore, the Strategic Research Agenda of the Joint Programming Initiative (JPI)[4] Cultural Heritage and Global Change defined heritage science infrastructures as an 'enabling activity', an ambition to be fulfilled through E-RIHS.

E-RIHS ARCHITECTURE

E-RIHS ERIC[5] is a consortium of partners with a formal structure and two operational levels, shown only schematically in Figure 1, as the real structure is still evolving:

(i) a Central Hub that operates transnationally as the access point to the RI;

(ii) National Hubs that operate at national levels in diverse legal frameworks and represent national associations of Partners.

Members may be European Union countries, other countries or intergovernmental organisations.

Technically, E-RIHS ERIC is based on partners offering their research capacity and delegating the decision on how to allocate it to the infrastructure consortium, whose coordination activities are paid by national contributions.

Submitted projects will be chosen on the basis of excellence. In return, partners take part in high-quality transnational collaborative projects.

E-RIHS Partners also benefit from:

- access to E-RIHS expertise exclusively offered by the partnership network;
- preferential access to research facilities within the E-RIHS partnership;
- facilities enabling them to jointly develop research and project consortia, courses or dissemination/engagement activities;
- preferential access to consortia applying for funding (using the E-RIHS label);
- option to have in-house training recognised and integrated into the E-RIHS Academy;
- association with the E-RIHS label;
- participation in forums regulating access and standards of quality (Access Board);
- access to Central Hub funding for small projects or emergency funding.

EXAMPLES OF CO-OPERATION

Through the previous programmes funding access to infrastructure (IPERION CH, http://www.iperionch.eu/), ample excellent examples of cross-disciplinary collaboration have been developed. Two are presented here[6] with the hope that they provide a stimulus to enhance future collaborations within E-RIHS.

Example 1– ARCHLAB case study: The Renaissance bronzes revisited

Users: Vaclav Pitthard, Sabine Stanek

Venue: Opificio delle Pietre Dure, Florence (IT)

The scope of this project was to re-review and follow-up an earlier project of the Kunsthistorisches Museum Vienna (KHM) dealing with organic patinas on bronze sculptures from the collections of the KHM. Data collected at the KHM were compared with those stored in the Opificio delle Pietre Dure (OPD) archives.

Both the KHM and the OPD in Florence have already been deeply involved in this field. Particularly in the OPD, studies on the composition of bronze alloys and coatings, the casting techniques and the provenance of these artefacts have been carried out. In the KHM, research into organic coatings (patinas) has been performed in addition to provenance research. The small bronzes have a long tradition of art historical study and connoisseurship, including a fine appreciation of their surface ‘patination’. Although many of the original surfaces of these bronzes have undoubtedly been altered through environmental conditions and aesthetic interventions, it was felt that no description of these bronzes would be complete without taking into account their surfaces, including their preparation and subsequent fate. The uniqueness and cultural importance of the bronzes raised interest in studies of their surface treatments. To better understand the conditions of the single object, to assist the art-historical interpretation and to enable the development of the best-suited conservation treatment, extensive scientific

Figure 2. Vaclav Pitthard presenting to the Opificio's conservators, students and scientists the scheme and the outcome of the project on organic patinas on bronze sculptures from the collections of the KHM

investigations of the composition of the materials was necessary. A full understanding of the nature of materials analysed in minute quantities requires scientific investigations using advanced hyphenated analytical techniques, as a combination of various supplementary techniques may be the best approach to gaining adequate results on such complex samples.

Previous analyses using gas chromatography–mass spectrometry (GC–MS) showed that the 'patinas' were quite similar in terms of their composition, mainly oil or oil-resinous varnishes. The specific colour of the coatings applied to the surfaces of the bronze statues did not necessarily involve pigments, but when it did they were used in relatively small amounts. Instead, the colour developed by baking the varnished metal. Thus it seems that both the final tint, which consisted of different shades of browns, ranging from light yellowish-brown, red-brown to dark brown and to black, and the structure of the organic coating, which ranged from thin, transparent to thick, opaque layers, does not greatly depend on the materials used but on the process of their application on the surface, such as with respect to the thickness of the varnish film, whether this is accomplished by adjusting the viscosity of the varnish or by multiple applications.

The OPD archives contain reports and analytical data on many Renaissance bronzes. The surface of these bronzes was studied mainly by Fourier transform infrared (FTIR) spectroscopy, both with a bench instrument on fragments and cross-sections and, in recent years, with a portable, non-invasive device. For the KHM staff, the experience of their OPD colleagues was very valuable (Figure 2), as it demonstrated the advantages of portable reflectance FTIR for non-invasive studies of the patination on individual bronzes and for selecting areas where meaningful micrometre-size samples could be extracted.

The FTIR spectra showed the material complexity of the samples but the interpretation and identification of particular materials was nonetheless immensely difficult. The visit to the OPD by KHM staff was also useful to strengthen personal communications and collaboration between the scientists of the two institutions. For instance, newly varnished mock-ups (bronze coupons) produced at the OPD were shared with the KHM, with the aim of studying the changes in the patinas' composition caused by the baking process. This was accomplished at the KHM using GC–MS before and after thermal treatment.

Example 2 – FIXLAB case study: NETS-NUBIA – A neutron tomography study of pottery forming techniques in Lower Nubia, Egypt, 4th–2nd millennium BC

User Lead: John Gait

Venue: BNC, Hungary

The aim of the project was to investigate the suitability of non-destructive neutron computed tomography (CT) as a means of identifying the forming techniques used in the production of ancient organic-tempered pottery. Specifically, a three-dimensional (3D) model was created of the distribution of the voids/carbonised particles left within the ceramic matrix resulting from the complete or partial combustion of organic fibres, within samples

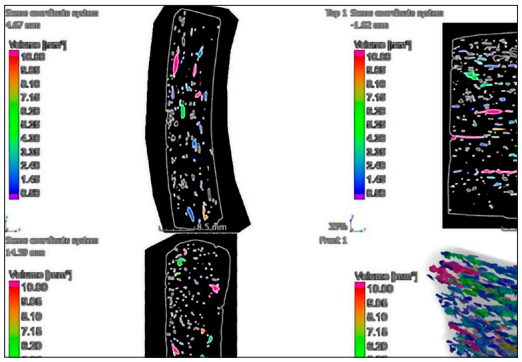

Figure 3. Vertical (bottom left), horizontal (top left) and tangential (top right) planar sections, and 3D reconstruction of a sample from an experimental coil-built ceramic vessel. Segmentation and evaluation of the orientated pore structure undertaken using VGStudio Max 3.2 based on neutron tomography carried out at the RAD station of the Budapest Neutron Centre (BNC), Hungary (Dr Zoltán Kis was responsible for the instrument

of ancient pottery and modern replicas (Figure 3). It was hypothesised that a statistical analysis of the orientation of these fibrous voids/particles in 3D space would lead to the detection of preferential alignments that in turn might correlate with suspected or known forming techniques. This information could then be used to further refine the detection of preferential particle alignments by more conventional, and less expensive, modes of analysis, in particular by petrographic analysis of ceramic thin sections or two-dimensional (2D) X-ray radiography.

Preliminary results indicated that neutron CT is able to successfully detect the remains, either as voids or carbonised particles, of fibrous organic temper in both ancient and modern pottery. Based on prior information on the expected size and shape of the organic particles (gathered from petrographic and microscopic examinations), a suitable range of filter parameters was established that allowed the fibrous organic inclusions to be isolated from the surrounding ceramic matrix and inorganic inclusions. This filtering permitted the orientation of the fibres to be visualised both in 3D models and 2D slices; the latter were used in visual comparisons with petrographic thin sections. Statistical analysis of the 3D models demonstrated that differences in the mean particle orientations in the modern experimental samples could be correlated with known forming techniques. Statistical analysis of the archaeological samples is still ongoing.

These very positive preliminary results demonstrate the potential of this novel analytical approach to the study of forming techniques in ancient pottery.

COLLABORATION BETWEEN DISCIPLINES – TRANSCENDING BOUNDARIES

With the long-term objective of establishing a fully functional E-RIHS, 24 different EU and global partners have applied for and were subsequently granted funding under the Horizon 2020 programme to continue providing transnational access to excellent facilities within FIXLAB, MOLAB and ARCHLAB, for three years. DIGILAB will be set up later within E-RIHS. IPERION HS is the next evolutionary step in the long line of successful initiatives supported by the EC Framework Programmes, and is the immediate successor to IPERION CH. It is a giant step in approaching the planned future dimension of the E-RIHS ERIC. Indeed, several institutions in both North and South America have already shown interest, and discussions are ongoing with others (http://www.e-rihs.eu/international-collaborations/). The discussions on E-RIHS ERIC currently include 54 transnational access providers and will accommodate 745 users over the three-year period, covering 325 access projects.

The current IPERION HS initiative has been reaching out to the different heritage communities, such as the social sciences and humanities community including curators, conservators, heritage managers, palaeographers, codicologists, art historians, historians, social scientists and other scholars already well engaged or looking to engage with the heritage science community. Other sectors, among them those of the Built Heritage and Archaeology, will also be addressed. This will ensure the development and

examination of cross-disciplinary research questions. There is sufficient scope to even further involve the conservation community in this exciting initiative, as one of the core functions of this new and far-reaching proposal for transnational access is outreach to all heritage sectors, to ensure that the research being carried out is appropriate, necessary, relevant and accessible to as wide a corpus of heritage professionals as possible.

One important way in which this inclusion can be achieved is through initiating discussions with the wider heritage community on how this multidisciplinarity should be developed and what can be achieved through the pooling of diverse resources. Bringing specific skills and expertise on board to enhance and strengthen the multidisciplinarity required by heritage science issues is key to the success of E-RIHS. This is to be addressed first by IPERION HS, by approaching these communities directly and engaging them in discussions on how an E-RIHS can help foster better heritage research. ICOM-CC, ICOM and the IIC are all well-established bodies with a very strong membership, with whom jointly organised sessions at common events and conferences can promote a better understanding of the IPERION HS community and the development of a community that includes all heritage professionals. At the end of these discussions, a report on how the research needs of the social sciences and humanities community could be addressed using heritage science research facilities will be formulated to help strengthen this aspect of E-RIHS.

To date, most users have been intensively involved in heritage scientific research, as illustrated in the above examples. However, future initiatives should expand the remit and more intensively involve researchers from other interdisciplinary heritage fields. A first step would be to identify the most suitable fora where discussions can take place to create a shared plan on how to collaborate and take full advantage of the unique research infrastructure.

Possible avenues of collaboration include curators, historians and art historians making use of ARCHLAB to access some of the most prestigious global collections, including their archives and other collections (e.g. collections of samples taken for analyses) and the expertise of the professionals who manage these collections, as well as other resources such as documentation centres and large and small-scale installations.

Conservators can exploit this infrastructure to study problems associated with an object, series of objects or entire collections, such as by comparative studies of similar objects held by other entities, to identify and characterise a particular deterioration phenomenon based on comparisons with other objects in a similar state that are stored elsewhere. This information might reveal the best possible treatment, when treatment is needed. Doctoral and post-doctoral students will also have access to an integrated platform that aids and promotes access to the best research and analytical facilities.

Thus, one of the core functions of this new and far-reaching proposal for transnational access is outreach to all heritage sectors to ensure that the research being carried out is appropriate, necessary, relevant and accessible to as wide a corpus of heritage professionals as possible. This is an innovative step that will certainly benefit heritage across the globe

in an unprecedented way. This paper is a first step in reaching out to the conservation community in its widest sense.

CONCLUSION

The ambition of a global shared infrastructure for heritage science is multiple: (i) catalysing new cross-disciplinary research by mobilising expertise and researchers in the humanities and natural sciences; (ii) building state-of-the-art tools and services for research communities and the heritage industry; (iii) leading the way in the development of digital platforms for the improved understanding, visualisation and use of heritage; (iv) integrating world-class facilities across Europe, and later across the world, to connect the global community of heritage science for the benefit of everyone's heritage; (v) driving scientific excellence and innovation through visionary research projects; and (vi) developing skills and capabilities to build strong cross-disciplinary science and foster collaboration. This paper has pointed out the numerous benefits of a co-ordinated research infrastructure to the conservation community, also in a cross-disciplinary sense, and the importance of inputs from this community in shaping the infrastructure in the future, for the benefit of the heritage of all.

NOTES

[1] The PARTHENOS (Pooling Activities, Resources and Tools for Heritage E-research Networking, Optimization and Synergies) research infrastructure aims at strengthening the cohesion of research in the broad sector of linguistic studies, humanities, cultural heritage, history, archaeology and related fields through a thematic cluster of European Research Infrastructures.

[2] The SSHOC (Social Sciences & Humanities Open Cloud) project creates the social sciences and humanities area of the European Open Science Cloud (EOSC).

[3] The Group of Senior Officials (GSO) of the EU on Global Research Infrastructures

[4] Joint Programming Initiatives (JPI) are developed in a structured and strategic process where EU countries agree on a voluntary basis on common visions and Strategic Research Agendas (SRA) to address major societal challenges.

[5] The European Research Infrastructure Consortium (ERIC) is a specific legal form that facilitates the establishment and operation of RIs with European interest.

[6] The results of these projects have been disseminated primarily as oral presentations and posters at conferences as well as poster presentations. Information was obtained for the paper by direct communication with the researchers. Further information is available on the IPERION CH website as case studies; the relevant URLs are given in the References.

ACKNOWLEDGEMENTS

The authors wish to thank the following for their input and contribution to this paper: Luca Pezzati, Vaclav Pitthard, Sabine Stanek, Monica Galeotti, John Gait, Katalin Bajnok, Zoltán Kis, Veronika Szilágyi, Adam Gibson and May Cassar.

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To cite this article:
Cassar, J. and M. Strlič. 2021. The opportunities of a global, shared research infrastructure for the conservation community. In *Transcending Boundaries: Integrated Approaches to Conservation. ICOM-CC 19th Triennial Conference Preprints, Beijing, 17–21 May 2021*, ed. J. Bridgland. Paris: International Council of Museums.