http://dx.doi.org/10.7494/human.2017.16.2.67

Anna Olszewska*

AGH University of Science and Technology

Joanna Gancarczyk**

University of Bielsko-Biała

MUSEUM AS A VISUAL LAB? CULTURE-TECHNOLOGY NETWORKS IN CBIR PROJECTS

Should any museum or scientific library consider itself as an information technology laboratory? This article explores the lives of several pioneering museum and library projects focused on digital image retrieval techniques (CBIR). The research aims to contribute critical evaluation of museum and information technology domain relations in the field. The outcomes may be applied in the planning of future co-operative endeavours. The analysis begins with a discussion of projects in which a museum or library played the role of data provider for image analysis development and testing (i.e. SWIC, Collage, SHREW systems). This is followed by a study of schemes focused on technology and implementing a standard image search methodology used for access to museum collections (i.e. QBIC, Artiste). The final part of the paper deals with the projects animated by museums or libraries themselves (BSB, Oxford Ballads Online, PrintArt) and the example of a consort that focuses on the specific type of visual resources (the Bernstein project).

Keywords: visual culture, image recognition, digital image retrieval, museum, library

Should any museum or scientific library consider itself as an information technology laboratory? Strategic documents and research in the field tend to present contemporary cultural institutions as receivers of innovations rather than as new technology providers (Knell 2010: 435-453; Bautista 2013). However, careful observation of links between the museum/library sector and computer science representatives show that in some cases museums and libraries have been providing an institutional framework as well as methodologies indispensable to the development of information technologies. The role museums play in dissemination of new media experiences, thanks to the presence of the audience, has been recently highlighted by Anne Balsamo in her studies on public interactivities (Balsamo 2016). Another field of activity emerges when we look at the contemporary museum as an institution possessing a significant

* Corresponding author: Anna Olszewska, AGH Akademia Górniczo-Hutnicza, ul. Gramatyka 8a, p. 407, 30-071 Kraków; e-mail: aolsz@agh.edu.pl.

** Corresponding author: Joanna Gancarczyk, Akademia Techniczno-Humanistyczna w Bielsku-Białej, ul. Willowa 2, 43-309 Bielsko-Biała; e-mail: jgan@ath.bielsko.pl.

amount of carefully digitized, professionally described and highly standardized visual data. The idea of the library/museum becoming a technology provider can therefore also apply to the domain of content-based image retrieval (CBIR) technologies.

This article explores the lives of several pioneering CBIR – museum and library projects. The research aims to contribute critical evaluation of museum and information technology domain relations in the field. The outcomes may also be applied in the planning of future co-operative endeavours.

The socio-cultural context of CBIR to art history application has been the subject of a few studies dealing with the rise of digital art history (Bentkowska-Kafel, Trish and Hazel 2005; Zweig 2015). In the subsequent paragraphs a user-experience oriented survey of visual search projects connected with museums and libraries will be presented. Special attention will be paid to the factors that influenced the project's maintenance and lifespan. The number of projects undertaken to date and the state of knowledge about visual arts enables us to compare a number of strategies applied in a variety of pioneering university research projects. The analysis begins with a discussion of projects in which a museum or library played the role of data provider for image analysis development and testing (i.e. SWIC, Collage, SHREW systems). This is followed by a study of schemes focused on technology and implementing a standard image search methodology used for access to museum collections (i.e. QBIC, Artiste). The final part of the paper deals with the projects animated by museums or libraries themselves (BSB, Oxford Ballads Online, PrintArt) and the example of a consort that focuses on the specific type of visual resources (the Bernstein project). The projects under discussion are listed in chronological order in Table 1. These cooperation models are juxtaposed in order to explore the consequences of museum-technology provider relations, as well as the longevity and cultural impact of visual search practices sustained by the museum or library.

We hypothesize that the museum activity in the field of visual analysis is indispensable if it aims to maintain its educational role. We state that turning a museum into a visual laboratory would be the best way to transmit the state of knowledge of art history to the to the digital circumference.

Table 1. Museum / library visual search projects, basic data

Project	Number of images included	Availability / form of publication	Lifespan
Morelli	1 000 (test set)	research study, in-house database	c. 1986–c. 1993 (incorporated into Van Eyck project)
ART MUSEUM	not given	research study, in-house database	1989–1992 (?)
QBIC	2 000 (for the X Windows prototype version)	IBM commercial search engine, DB2 extension	1993–2014 (suspended)

Table 1. cont

SWIC	3 000	online database	1996–2007
COLLAGE	36 000 (22 400 online)	in-house database online database	1995 (online since 1998)–2003
ARTISAN	10 000	in-house database	1997–2005 (?)
SHREW	806 (tracings reported)	online database in-house database	2000–2006
Artiste	1000 (trial version)	research environment online prototype for AUIG members	2000–2002; 2004
PROFI	367 000	in-house database online demo database standalone software	2004–2007 (partially accessible in 2016)
Van Gogh brush-strokes	101	research study	since 2006
M4ART	not given	online prototype search engine	2006
Bernstein's Memory of Paper	–	Standalone software, Matlab source codes	2006, 2009
PrintArt project	988	research study, database, Matlab source code	2010–2013
BSB image similarity search	5 400 000	online database	since 2011 (online since 2013)
Oxford Ballads Online	8 000	online database	since 2012

MUSEUM/LIBRARY AS AN IMAGE PROVIDER FOR VISUAL SEARCH INITIATIVES

Medicine, along with the other areas of natural studies, and the military industry form the main fields for the exploitation of numeric image analysis. Visual forms studied by art historians, as well as abstract trademark signs, logotypes and shapes of old paper watermarks, are amongst other sets of images which may be used in content-based image retrieval (CBIR) testing. Toshikazu Kato, who is acknowledged as the author of the CBIR acronym, was probably the first to create this kind of database as part of his pioneering projects back in 1989 (Kato, Kurita and Sakakura 1989). Among the early projects, W. Vaughan's "Morelli" should also be mentioned (Vaughan 1987). Images from museum and library collections, as they benefit from careful and professional categorization and cataloguing, have since been regularly used for CBIR development and evaluation purposes.

SWIC

Among the earliest projects of this kind was SWIC (search watermark images by content). It was created by the Computer Vision Group of Geneva University. Schweizerisches Papiermuseum in Basel cooperated in the late stages of the project (Rauber, Tschudin, Startchik and Thierry 1996; Rauber, Pun and Tschudin 1997). First published in 1996, SWIC was funded by grants from the Swiss Federal Government. The prototype database contained 3,000 historical watermarks. The demo version of the database remained live on the university webpage until 2007 (The SWIC Project).

This database enabled textual, morphological and shape-based search of historic watermarks (Figure 1). The same modus operandi appears to have been retained for later versions of the project. Basic visual data descriptors were extracted in advance, during the digitalization phase. The authors found contemporary automatic image extracting unsatisfactory (Rauber, Pun and Tschudin 1997: 1). For that reason, the initial set of images in the database consisted of drawings found in the Briquet catalogue, the fundamental publication on watermarks (Rauber et al. 1996: 19). In consequence, Briquet's standards became crucial for future SWIC image adjustment and information retrieval planning. While designing the shape retrieval algorithms the authors assumed that the input images were going to be the same in scale, un-rotated and attached to the chainline marks visible on the paper. Features such as height and width of the watermark, as well as distance between chainlines or selected shapes were stored in the separate data structures – hash tables. Quick data access would have to be enabled to make search time satisfactory. Topographical notation of the morphological features was quite exact. A list of nine dimensions was offered. The morphological features included the size of the image, number of regions, the respective locations of the three largest areas, and the number and positions of the junctions in the image (Rauber, Pun and Tschudin 1997: 3).

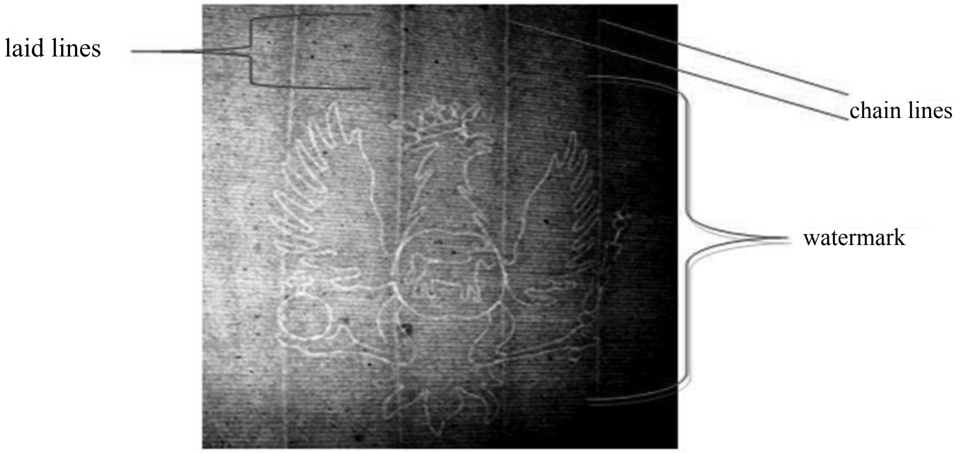

Figure 1. Backlight image of a historic paper sheet with a watermark

Designers of this search engine were aware that future development of image segmentation methods should make shape retrieval possible for images from outside of the database as well. Because of this, comparison methods invariant to scaling, rotation and translation were also taken into account (Rauber, Tschudin, Startchik and Thierry 1996: 24). This strategy was adopted for the shape retrieval solution the SWIC designers proposed. Simple statistics measurements which would be enough for non-standardized Briquet images in the database were supplemented by similarity algorithms connected to the expert query. It worked with input images normalized according to size. The comparison methods utilized here achieved an 86% performance rate for the non-variant search (identical scale, unrotated image). The evaluation tests proved that to obtain the closest match the user needed to obtain nine returns out of a group of 120 (13% of tested samples) (Rauber, Pun and Tschudin 1997: 5–7).

The method of the image query could be selected by the user, making it possible to ask not one but a few ‘visual questions’. This project’s benefits derived from demonstrating that a selection of search options should be adjusted in line with the user’s level of digital literacy. Complicated applications compromise the user’s ability to achieve satisfactory results, while an oversimplified search engine arouses suspicion. This might be one of the reasons why, despite a long list of search algorithms, SWIC did not redefine contemporary watermark image search practices. A few more factors contributed to the relatively low impact of this database. Because of its innovative nature, the project predated the era of digitization in museums, but as it was designed to be maintained by a single administrator, it probably did not fit in with the museums’ organizational and administrative processes. It is not known whether SWIC was actually used by the Paper Museum in Basel. Back in the 1990s the museum seemed to have no online presence. Exploration of the possibilities of digital image analysis seems to have been the point of the project. It allowed for new methods to be developed and tested. In the future, the museum would serve as resource provider and look after the operational site of such a database.

NORTHUMBRIA UNIVERSITY’S CBIR RESEARCH: COLLAGE AND SHREW DATABASES

Established in 1997, the Institute for Image Data Research (IIDR) at the University of Northumbria in Newcastle focused on digital art history studies. Members of the Institute’s staff (i.a. Margaret Graham, Jonathan Riley and John Eakins) were involved in a series of research projects connected with the museum and library historical resources retrieval. Evaluation of user experience and application of Gestalt psychology principles were amongst some of the distinctive features of the IIDR research projects. To begin with, it is important to mention the creation of the COLLAGE (‘City of London Library & Art Gallery Electronic’) database. This resource, with its 26 000 online images, was probably one of the biggest visual search engines created at the time (Ward, Graham, Riley, Ney and Eakins 2001). The reason for incorporating a commercial CBIR application into COLLAGE was to ‘assess the effectiveness’ of CBIR (Ward, Graham, Riley and Sheen 2002). The database became active in 1997, to begin with exclusively as an in-house service. In 1998, it appeared online.

The CBIR for COLLAGE developed as a research project by IIDR. Its authors highlighted that the 'end-user evaluations are critical to evaluating enhanced technology' (Ward, Graham, Riley and Sheen 2002). For this user oriented study, the visual search interface was highly simplified. The search components regulation switches were descriptive, for example: 'not important' or 'very important'. The retrieval process accounted for such features as texture, shape and colour. The default option prioritised structure (60 out of 100 points), while shape was secondary (29 points) and colour was of no importance (1 out of 100). Users had no freedom to add images for comparison.

At the time of writing, the COLLAGE word search option is being supported by Imedia Corporation. The visual search option was available only in the early version and was removed after 2003 (The Collage database).

Another IIDR initiative connected with museum/library resources was the creation of a content-based retrieval system for historical watermark images, known as SHREW (Figure 2) (SHape REtrieval of Watermarks). It was developed between October 2000 and March 2002. The related database was to be called the Northumbria Watermark Archive. The authors stated that the Archive was to become 'an important resource for teaching and research in art conservation within UNN' (The SHREW project). Nevertheless, the project seems to not have evolved beyond the prototype stage. Its only outcome is a collection of approximately 800 radiograms of historic paper watermarks, some of which were provided by the Koninklijke Bibliotheek. There seems to have been no online access to the prototype database after 2006.

SHREW was actually used as a test database that enabled evaluation of the efficiency of shape retrieval methods (Riley et al. 2002: 256–260). The IIDR team assumed that 'image retrieval success is evaluated on how the systems' selection of images compares with those images perceived as similar by the human observer (i.e. the ground truths)' (Eakins et al. 2001). The Northumbria group intended to continue their work on shape comparison, developed previously in their trademark CBIR search projects ARTISAN 1 and ARTISAN 2. The SWIC initiative was mentioned in the Riley at al. publications. The online project description remarked on its small scale, and on the lack of comprehensive reports on the retrieval returns (The SHREW project).

Figure 2. The SHREW interface http://www.unn.ac.uk/iidr/research/wmarks/wmarks.html fragments available via http://archive.org/web/

The Northumbrian group has established a separate series of museum-related research. Their projects were inter-related and concentrated on specific features of heritage collections. SHREW algorithms were based on Artisan I and II research findings and conclusions, as well as on lessons learned from COLLAGE. The PROFI trademarks and logotypes comparison research, launched in 2007 by Remco Veltcamp from Utrecht University, is a good example of an external initiative continuing the work of IIDR (PROFI project description 2004–2007: 11).

The direct impact of the IIDR's short-lived projects was somewhat restricted to the contemporary academic sector. After a year of COLLAGE activity, the feedback user reports delivered only 180 questionnaire responses (Ward Graham, Riley and Sheen 2002). Nevertheless, it is valuable as one of the very first sets of data documenting user experience in the visual search context. Some of the responses can be used to provide guidance for the future work in this area. IIDR projects were also significant for disseminating the ideas of visual search at the level of local archives and in the museum sector. The British Library and the UK Patent Office were among the institutions that provided financial support for this research (Eakins, Graham and Boardman 1997: 186).

IMAGE PROCESSING FOR ARTIST IDENTIFICATION – WHY DID COMPUTER SCIENTISTS SUDDENLY "FALL IN LOVE" WITH VINCENT VAN GOGH'S ART?

Museum or library digital resources may become highly suitable for CBIR scientific projects because of their specific information content. Compared to digital photography, digital images of prints and even paintings tend to contain much less information at the low-feature level, like texture, colour and depth. On the other hand, it is possible to examine other elements such as brushstrokes, and this provides information about technique and tools used by an artist, thus enabling identification of individual styles through numerical measurements. Historical art objects have been within the interest of a number of computer science researchers from the very beginning of image processing and analysis in general, throughout Europe (Bucklow 1998; Barni 2005; Cappellini 2003) and worldwide (Stork 2003; 2005). However, several factors limited research progress on a large scale. These included a lack of high quality and easily accessible research material in the form of high resolution, digital image libraries.

On the other hand, as mentioned above, museums and libraries began creating digital repositories to document their collections. The need for cooperation between art historians and computer scientists became reality in 2006, when the Van Gogh and Kröller-Müller Museums in the Netherlands produced a dataset of 101 images of paintings in their collections and made them available to image processing researchers, mathematicians, electrical engineers, and statisticians from several different universities (Johnson 2008). The images were obtained as high-resolution grayscale scans of existing Ektachrome films, scaled to a uniform density of 196.3 dots per painted inch and digitized to 16 bits per channel. Out of the 101 paintings, 82 were van Goghs, six were known not to be by the artist, and attribution of the remaining 13 was questioned by experts.

Three research groups: from Pennsylvania State University (J. Li, J. Wang, and W. Ge), Maastricht University (E. Postma and I. Berezhnoy), and Princeton University (I. Daubechies, E. Brevdo, and S. Hughes) were asked to work simultaneously on the dataset for six months and to present their results in a workshop at the end of that period. The aim of the research was to investigate the possibility of automatic classification of any artist's painting style. All three teams discovered that based on brushstroke characteristics, mainly obtained by the wavelet transform which highlighted dissimilarities between painting styles, it was possible to determine which paintings were by van Gogh and identify those which were previously attributed to the master but were not by his hand. For example, copies registered a higher concentration of high spatial frequency content than originals. This corresponds to an increased number of small touches, which, as explained in the workshop proceedings (Johnson: 2008), reflects the copyists' tendency to use several touches to approximate the desired effect which the master would have obtained with a single stroke.

It is worth noticing that the Van Gogh and Kröller-Müller Museums' research project set a trend which thanks to rapid technological growth was followed by other museums and institutions. Museums now produce high resolution, carefully prepared and labelled digital copies of artworks and either make these available to the public on their web pages, or share them with professional groups of scientists for research purposes. For example, Rijksmuseum and Hermitage Museum both have a "Highlights" section in their online galleries, searchable collections of high resolution digital scans of the artworks from their collections. The *Closer to van Eyck* project (Closer to van Eyck) supported by the Getty Foundation produced, besides scholarly reports, a digitised image of the Ghent altarpiece available online. The Haltadefinizione LAB offers very high-resolution images of artworks for the public, as well as for professional and commercial use (including Leonardo da Vinci's 'Last Supper') (Haltadefinizione).

The challenge which emerges from these projects may be to incorporate both the public and professional contributions and provide a framework for solving the issues which art historians have highlighted in their research. That this is possible was demonstrated by large projects in other academic fields, such as the *Planet Hunters Project* (The Planet Hunters) created to engage the public to help search data from NASA's Kepler spacecraft. This is one of a group of projects that enlists volunteers to assist researchers in dealing more effectively with a vast quantity of available data.

WHEN THE MUSEUM IS ABSENT: EXAMPLES OF THE AUTOMATIC DISCOVERY OF ARTISTIC INFLUENCE PROJECTS

Some research teams decide to collect test images from heterogenic repositories, use information and examples published both in and outside the professional art history services, and describe the test sets in a rather general way.

We can trace this tendency in numerous projects dealing with the issues of artistic influence and attribution. Van den Herik, Postma (2000) and Lombardi (2005) use a set of paintings selected from the Nicolas Pioch WebMuseum. Vanrell et al. present their data set as a collection of paintings by Ingres, Matisse, Monet, Picasso, Rembrandt, Rubens, Titian, and Van Gogh without providing a list of works or provenance (Vanrell et al. 2010).

The same strategy was also applied in recent research by the Art and Artificial Intelligence Laboratory at Rutgers project. The Laboratory was founded on the basis of the Computational Biomedicine Imaging and Modeling Centre. In the Automated Artistic Influence Discovery project the research team asked: *"Is influence a task that a computer can measure?"* (Saleh et al. 2016) presenting the famous example Diego Velazquez's Portrait of Pope Innocent X (1650) reinterpreted in Francis Bacon's study (1953) (cited in Saleh et al. 2016). The data set is declared to consist of '1710 high-resolution images of paintings by 66 artists spanning the time period of 1412–1996 and containing 13 painting styles'. These were collected from Mark Harden's Artchive database. The set was expanded with Wikiart paintings in later studies (Elgammal and Saleh 2015). A ground-truth data set for the task of artistic influences is declared as containing primarily positive influences recognised by art historians. It is intended to be used only for evaluation of confirmed or suggested influences. The authors refer to two resources in this context: The Metropolitan Museum of Art and The Art Story Foundation webpage. The latter is a non-profit organisation in a strategical partnership with a company called Meural Canvas, which purchases art-dedicated digital displays.

This approach gives way to collective narratives on art history, and includes open-sources compiled by art enthusiasts and digital practitioners. However, it often makes the basic data hard to verify, and does not guarantee the appropriate calibration of images nor the consequent classifications of period, style, iconography etc.

MUSEUM AS A BENEFICIARY OF TECHNOLOGICAL SOLUTIONS

Much has already been done in the effort to incorporate computer image analysis techniques to deal with the fundamental requirements of such disciplines as art history, library studies and conservation. Far from being perfect, the CBIR methods may meet with a lack of interest from the museum side if they are regarded as a ready-to-use product. This is what has happened in relation to some now-suspended projects.

QBIC – THE FIRST COMMERCIAL CONTENT-BASED IMAGE RETRIEVAL ENGINE

In 2014, the Hermitage's website was moved to a new service. With the new version, the QBIC (Query by Image Content) search option by IBM is no longer available to the museum's on-line visitors. However, IBM and the Hermitage continue to cooperate in other domains.

The very first version of QBIC, developed in the IBM Almaden Research Centre, was implemented as an X-Windows application and tested on a UC Davies database of 2,000 images scanned at 24 bits of colour and 1000 dpi. The basic goal of this implementation was to enable visual image classification without naming a medium, category or object, and search of images on the basis of their visual qualities, such as shape, texture, and colour. The QBIC prototype system (Flickner 1995; Lee 1994; Flickner et al. 1995) considered two main data types: scenes and objects. A scene is a colour image or single video frame, and an object is a part of a scene. All the objects in the images had to be manually outlined. These outlined areas were then stored as "masks" in a file associated with the image, thus allowing creation of detailed “visual indices” for the database images. All the colour and texture features of images and objects had to be computed at the stage when the database is prepared for the search. Subsequently a user browsing for a particular shape in an image could combine the text-based and visual search, beginning with a keyword or a handmade drawing on a screen. The relevant thumbnails found in this search could then be moved to the holding area and a new, combined shape and histogram-based search could be undertaken. According to Holt’s report (Holt et al. 1997), this software was able to identify approximately 50 per cent of images containing a particular object, for example a horse, exclusively by means of a visual search.The web version of QBIC appeared in 1997. As the manual outlining was labour-intensive and admittedly subjective, it was suspended in this version. However, new tools were introduced to allow for automatic performance of some visual search functions. For example, a new capability was added to the layout search that allowed searching for user specified colour in a given location.

Among other implementations, QBIC was used for a visual search module designed for the Hermitage Museum webpage. The State Hermitage Museum in St. Petersburg and IBM Research Group began their cooperation in June 1997, establishing a new Corporate Community Relations project. The state of the art technology delivered by IBM was used to open a vast collection of artworks to the public in four main areas: Image Creation Studio, designed to produce high quality, high resolution digital images from originals or transparencies of works of art from the Hermitage collections, Education and Technology Centre, Visitor Information Kiosks, and the Digital Library Supported Web Site, featuring a QBIC search engine (Hermitage Museum Project). The QBIC engine was able to locate a specific artwork using visual tools, e.g. by selecting colours from a palette or by sketching shapes on a canvas. Figure 3 shows the layout and colour interfaces for the QBIC search engine designed for the Hermitage Museum, according to a screenshot archived by Experimental CBIR (Experimental CBIR).

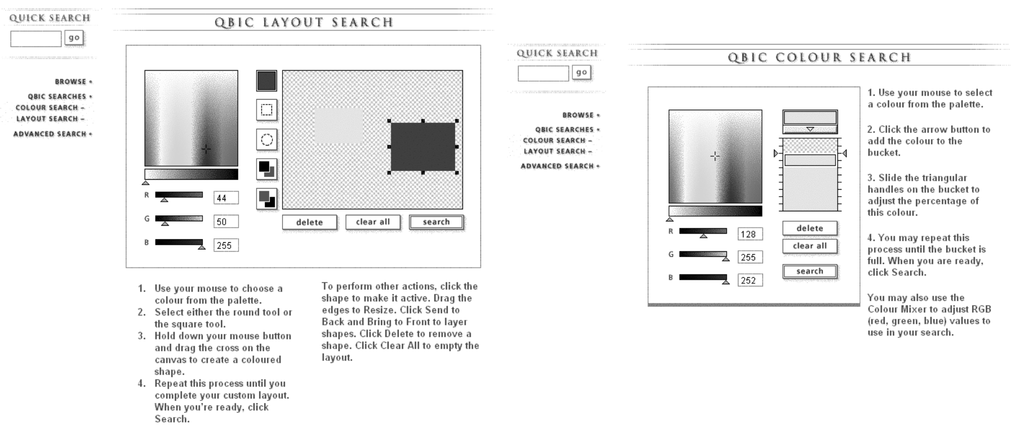

Figure 3. QBIC layout and QBIC colour search interfaces
for the Hermitage Museum webpage Artiste

ARTISTE

CBIR appeared not to be a priority of the museum in the case of Artiste as well (Figure 4). This project was realized as international collaboration in 2000–2002 and coordinated by NCR Systems Engineering Copenhagen (Denmark) in partnership with two other technical institutions: IT Innovation Centre (University of Southampton) and Giunti Interactive Labs (Italy). Among the museums involved were The National Gallery, Centre de Recherche et de Restauration des Musées de France, Uffizi Gallery and the Victoria & Albert Museum (Artiste 2002: 1). The aim of the project was to create a complex research environment that would enable cataloguing, research, and comparison of works derived from separate museum collections. Designing the image search was part of a larger project. The Artiste consort members planned to adjust existing retrieval methods to the museum's needs.

The Artiste prototype had no shape-based query. The main function was query by colour image histogram, and visible light image. Searching by texture and 'searching by fax' (low quality images) were among the additional options. The improvements proposed as part of the project included a system of comparing sub-images (details of an individual piece).

At the time, the use of the Artiste visual search package was limited to the publication of algorithms. Content-based navigation methods were not incorporated in the final version of the project due to a lack of interest on the side of the museums. This was noted in the project's final report: "As no requirements for the content-based navigation were put forward, (the research team) decided to re-prioritize the Dynamic Linking and Content based navigation work" (Artiste 2002: 30).

Figure 4. The Artiste interface: available via http://archive.org/web/ [2.04.2016]

MULTIMEDIA FOR ART RETRIEVAL (M4ART) – AN ONLINE ART RETRIEVAL SYSTEM FOR MUSEUMS

The prototype of the online Multimedia for Art ReTrieval (M4ART) system was presented by van den Broek et al. in 2006 (van den Broek, Kok, Schouten and Hoenkamp 2006). The system was created for, and the entire test was conducted on, the digitized collection of the National Gallery of the Netherlands (the Rijksmuseum). The main goal was to extend the existing text search method by adding a new system of querying by visual example. The example image could be uploaded from the Internet or the user's computer, or selected by browsing the museum's collection.

The visual search was performed by extracting information about the global colour, distribution and texture features (entropy, inverse difference moment, cluster prominence, and Haralick's correlation) of the sample image and comparing it with the same information about all the other images in a dataset. The distance between feature vectors containing the extracted parameters was computed by the Minkowski metric.

The M4ART search engine's layout was built according to a front-end user's requirements and followed guidelines provided by experts related to size and distribution of thumbnail images on the screen. The service was available for a period of time on the Vrije University in Amsterdam webpage at http://cai.nici.ru.nl/M4ART/ (Figure 5). However, the service is no longer supported, and its last images were archived in 2007. Rijksmuseum seemed to have not used the visual search options, except for a simple colour match function.

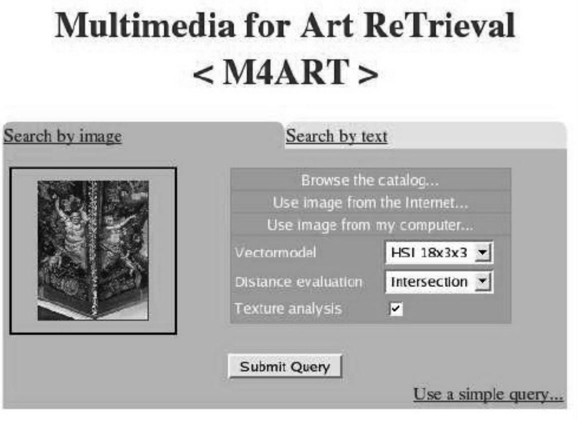

Figure 5. Layout of the Multimedia for Art ReTrieval (M4ART) prototype online art Retrieval system

THE MUSEUM-BASED INITIATIVES

The museum and library-based initiatives are the next step in the dissemination of visual search ideas.

BSB VISUAL SIMILARITY SEARCH (Figure 6)

The image recognition and image similarity search is an initiative developed by Bayerische Staatsbibliothek in Munich in cooperation with Fraunhofer Heinrich Hertz Institute Berlin (core technology provider) (Ceynowa 2013). It was instigated by Dr Markus Brantl (head of the Digitalisation Library Department) in 2011. The public online access to this engine has been available since 2013. According to statistics reported by Thomas Wolf it enables exploration of the vast repository of approximately 5.4 million images derived from digitized books, prints and manuscripts (83,000 items) (Wolf 2015). User's images, in .jpg format, can be uploaded for search purposes.

Figure 6. BSB visual similarity search interfaces: http://bildsuche.digitale-sammlungen.de

HHI software, created for the detection of image copyright infringements, became the basis for the BSB search engines. It is claimed that the visual search is purely numerical and independent of semantic descriptors. Colour and texture of images are given as basic features. Search preferences can be regulated by users with the help of a simple set of slides. The same mechanism allows for setting of the similarity level function (Ceynowa 2013). Image descriptors preserve statistical information about the image. The effectiveness of the topographical motifs disposition function is reduced because measurements are taken from segments of an image automatically divided into a sequence of squares. In consequence, the BSB gives the user an option to either find a 'similar image' (or a duplicate) or engage in a 'hit or miss search for the shape variation and congenial compositions. These methods should be efficient for matching the colour palettes, as well as for comparing prints and drawings: any images comprised of nets of hatchings, scratches or pen strokes: delicate, multiple motifs that make structure variation easy to identify in different fragments of a composition.

A glance at the growing BSB repository of 5 400 000 images demonstrates that it is essential to engage libraries in order to enable the development and use of experimental visual search functions. The BSB group focuses on supplying some well-proven, workable visual search solutions. The role of the digitalization department is to support the image analysis to become a part of the digitalization process and prepare the images for visual comparison. In such a partnership, the library is the stakeholder who develops new patterns of research, making it possible for the user to become acquainted with new solutions. The evaluation and feedback are left to be done in the future.

BODLEIAN BALLADS IMAGEMATCH AND THE PRINTART PROJECT (Figures 7–9)

Among the various modern library computer-aided visualisation projects, it is worth mentioning those search engines designed to serve a narrowly defined research area.

One of those is the Bodleian Ballads ImageMatch tool (Bergel et al. 2013). It was developed by representatives of the Oxford Visual Geometry Group (Relija Arandjelovic, Andrew Zisserman). As part of this initiative, curators and software developers cooperated to create a teaching device connected exclusively with specific research queries related to the collection of illustrated broadside ballads. The engine can be used to find copies, fragmentary prints, discern stages of the printmaking process, and identify the matrices which have been reused or merged.

The software was created using the SIFT method (Bergel et al. 2013), transforming the automatically detected edges into bags of visual forms (BOV). Topographical distribution of the measurements is omitted, making the search robust and invariant to rotation, scale, and changes to some image details. Since the user cannot manipulate the methods, it is possible to display the algorithm sequences on screen, enabling quick insight into each search formula.

This device has many features which enhance its efficiency and reliability, including a simple interface and a fast search engine. The ImageMatch is only partially integrated with the main Bodleian Broadside Ballads database, so only 8 000 out of 34 000 broadsides are accessible for visual comparison. Even though this database is small it is effective because all the iconic and most frequently studied examples from the entire repository are available for analysis.

Figure 7. Bodleian Ballads ImageMatch, queries displayed, http://imagematch.bodleian.ox.ac.uk:8000/

The Oxford project demonstrates that user-oriented design and presentation of specialized devices can help in wide and fast dissemination of new and constantly advancing visual search methods. The Bodleian Ballads ImageMatch received a great deal of positive feedback when the Visual Geometry Group's solutions were adopted for research of the print culture. They were chosen for a study of production, trade and circulation of 15th century Venetian woodcuts (The 15cBOOKTRADE Project).

Research on the print culture is particularly resonant to the study of the relationship between Portuguese tile panels and European art of print. It is known that the subject matter and composition of many of the 19th century tile panels have been inspired by prints created in the 300-year span of the 15th and 18th centuries. This was caused by a rapid increase in availability of artistic prints, which occurred in the 15th century due to dissemination of relatively cheap and fast methods of paper production and printing techniques.

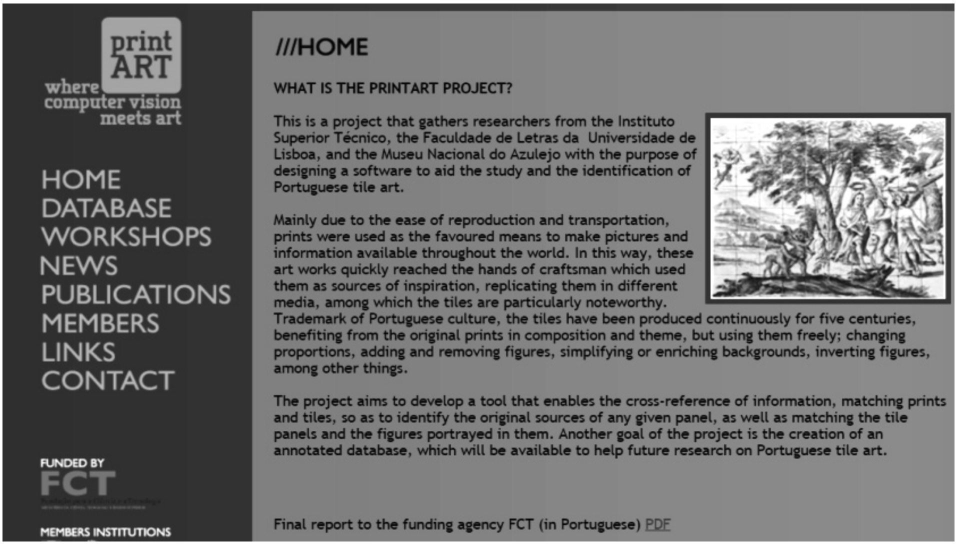

Figure 8. The PrintArt project information service, available at http://printart.isr.ist.utl.pt/

In 2006, the National Museum of Azulejo in Lisbon set up a new project called The Az – Azulejo Research Network (João Miguel dos Santos Simões' Thematic Network for the Study of Azulejo and Ceramics – RTEACJMSS)[1]. This aimed to provide a reference platform for research, inventory and documentation of *azulejos*, and to make information available to the scientific community concerning the manufacture and use of tile panels, catalogued and labelled according to scientific standards. Dynamic collaboration with external partners led to establishing a series of related scientific projects, among which the PrintArt – Content and Ontology Based Image Annotation and Retrieval project was established in cooperation with Instituto Superior Técnico / Universidade Técnica de Lisboa (IST/ISR-UTL). The main goal of the PrintArt project was to create an algorithm for automatic annotation and retrieval of art prints proven to have inspired Portuguese tile artists and manufacturers.

Research studies instigated and continued by Carneiro on his own (Carneiro 2011; Carneiro et al. 2012; Carneiro 2013) and in collaboration with Chen (Chen and Carneiro 2015) proposed two parallel research avenues, one being the automation of producing global annotations to previously unseen test images, the other focused on enabling retrieval of an un-annotated image from the database, given specific visual classes. Technically, this method follows a graph-based learning algorithm, relying on the assumption that visually similar images are likely to share the same annotations.

The PRINTART database introduced in 2010 (Carneiro 2011) comprised 307 annotated images with one multiclass problem and 21 binary problems, all images being collected from the Artstor digital image library (The Artstor database) and annotated manually by art

[1] In 2015 reorganized and given a new name Az-Rede de Investigação em Azulejo (ARTIS-IHA/FLUL), http://www.artis.letras.ulisboa.pt/default.aspx

historians. The selection of art prints was constrained by date (15th–17th century) and subject matter (religious theme). In 2013 (Chen and Carneiro 2015) the database was enlarged to 988 artistic images with global annotation keywords representing one multiclass problem (theme with 27 classes), and 48 binary problems, and face annotations, representing the main characters relevant to the theme of the image. Binary problems, in that representation, involve an annotation that indicates the presence or absence of a class, while multiclass annotation reflects exactly one class (from the defined set) related to the scene. Figure 9 shows an example of an image from the PRINTART database with global and local annotations produced by an art historian: global annotation is represented by the theme of Annunciation (one of the 27 multiclass keywords) and seven identified binary classes (seven subjects found in the image, each annotated by a keyword being one of the 48 defined binary problems). Local annotations describe the position of the identified binary class representative.

Theme / multiclass problem:
Annunciation

Binary classes:
Mary
Gabriel
Dove
Lily
Vase
Wing
Angels floating in the air

Figure 9. Example of the manual annotation of an art print in the PRINTART database. Theme (multiclass problem) and the binary classes found in the image are listed (Carneiro 2011)

Images in the PRINTART database are represented with the bag of visual words model (BOV), where each visual word is formed using a collection of local descriptors extracted by means of the scale invariant feature transform (SIFT).

The PrintArt project was supported in 2010–2013 and remained a research study, with no interface or search engine made available to the public. However, the PRINTART database, containing all the SIFT descriptors for 988 images used in the study, as well as the source code in MATLAB, is accessible on the PrintArt web Page (The PrintART project).

LIBRARY SOFTWARE AND TOOLKITS: BERNSTEIN MEMORY OF PAPER

The majority of the museum CBIR projects aim to create an online database. Publication of visual search tools in the form of an application can be regarded as a separate, not quite popular, yet very important trend in image research and development for a museum environment. This strategy was employed in the PROFI project (see http://profi.cs.uu.nl/software.cst), and was also pursued by The Bernstein Consortium. The main objective of the project was to create a cross-reference catalogue of historical paper watermarks. Paper expertise applications were proposed as its additional functions (Bernstein, final report 2009: 3). The coordinators of the program decided to publish several apps between 2006 and 2009. These light tools were intended to serve professionals during different phases of paper analysis (i.e. watermark shape extraction, chain and laid lines measurement, identical watermark retrieval). For this purpose, the Bernstein group gathered some previously designed programs, for example the ‘AD751’ created by Vlad Atanasiu in 2005 (Atanasiu 2004). Others, like the ‘Paper Analysis Tool’, or the ‘Automatic Watermark Detection Tool’ prepared by the Delft University group in 2009, were a combination of a few independent functions (Otal, Staalduinen, Paclik and Lubbe 2008). While doing so, the Consortium began a process of integration of several technological solutions and this led to the creation of specialized toolkits. Since the set of apps may be used independently for different image repositories, this type of visual search methodology may help to liberate visual search technology from the confines of the database formula.

CONCLUSIONS

The history of museum-technology relations in the field of visual analysis shows the evolution of cooperation strategies over the last three decades. Some of the early CBIR projects looked to the museum as a resource provider and a partner to implement experimental solutions. The next phase was founded on international European grants and library-IT company cooperation. This is when we observe activities of international consorts where the library/museum is a receiver of the technology within the R&D model. Museums have tended to initiate CBIR cooperation more often after 2005–2006.

The variety of cooperation models shows that the technology of visual searching designed to promote access to cultural and heritage resources is still in its experimental phase. The history of the projects demonstrates that the scale of any database is linked to the type of the institution for which it had been created. Projects affiliated to libraries and museums tend to produce larger repositories (see the example of BSB visual search). However, it is hard to say if the museum or library affiliation does help to sustain a projects’ online presence. Further investigation should be undertaken to verify whether the users’ primary need is for a more generalized or specialized search. The recent histories of the databases created for the print culture studies (see Oxford Ballads Online) show that even relatively small but highly professional groups of users can help to disseminate new tools by adapting them for their specific research purposes.

Our analysis confirms that museum activity in the field of visual analysis is indispensable if it aims to maintain its educational role. We have observed two reasons for which museum/library institutions should consider creating visual laboratories: (1) because it would be a space to formulate queries to be solved with the help of algorithms, and to adapt contemporary art history methods to the digital environment; (2) because the laboratory would provide pure datasets (ready-to-use packages of calibrated, correctly categorized opensource images and catalogue descriptions). The datasets would be used in visual experiments as well as in the process of introducing CBIR solutions to the museum's public. Creating a museum-IT technology network of this kind would increase the quality and social impact of CBIR projects.

REFERENCES

ARTISTE: *AnIntegrated Art Analysis and Navigation Environment*, in: *Final report for the IST FP5 project: IST_1999_11978*, 2002, http://eprints.soton.ac.uk/257427/1/ARTISTE_Final_report.pdf (22.04.2016).

Atanasiu, Vlad. 2004. *Assessing paper origin and quality through large-scale laid lines density measurements*, in: Rosella Graziaplena and Mark Livesey (eds.), *Paper as a medium of Cultural Heritage. Archaeology and Conservation: Proceedings of the 26th Congress of the International Paper Historians Association, 30 August – 6 September 2002, Rome/Verona, Italy*, Rome: Istituto centrale per la patologia del libro, pp. 172–184.

Balsamo, Anne. 2016. *The Cultural Work of Public Interactives*, in: Christiane Paul (ed.), *Blackwell Handbook of Digital Art*, New York: Wiley-Blackwell, pp. 331–351.

Bentkowska-Kafel, Anna, Trish Cashen and Hazel Gardiner. 2005. *Digital art history: A subject in transition*, London: Intellect Books, vol. 1.

Barni, Mario, Anna Pelagotti and Alessandro Piva. 2005. *Image processing for the analysis and conservation of paintings: opportunities and challenges*, "IEEE Signal Processing Magazine", 22(5): 141–144Bergel, Giles, Alexandra Franklin, Michael Heaney, Relija Arandjelovic, Andrew Zisserman and Donata Funke. 2013. *Content-Based Image-Recognition on Printed Broadside Ballads: The Bodleian Libraries' ImageMatch Tool*, paper presented at: IFLA WLIC 2013 – Singapore – Future Libraries: Infinite Possibilities in Session 202 – Art Libraries with Rare Books and Manuscripts, 2013, http://library.ifla.org/209/1/202-bergel-en.pdf [2.04.2016].

Bernstein, final report for the ECP 2005 CULT 038097 project. 2009.

http://www.bernstein.oeaw.ac.at/twiki/pub/Main/DocumentsArchive/Del32_D7.8_Final_Project_Report.pdf [2.04.2016].

Broek van den, Egon, Thijs Kok, Theo E. Schouten and Eduard Hoenkamp. 2006. *Multimedia for Art ReTrieval (M4ART)*, in: Edward Y. Chang, Hanjalic Alan and Sebe Nicu (ed.), *Multimedia Content Analysis, Management, and Retrieval*, "Proceedings of SPIE – The International Society for Optical Engineering", 6073: 341–352.

Bucklow, Spike. 1998. *A stylometric analysis of Craquelure*, "Computers and the Humanities", 31(6): 503–521.

Cappellini, V., M. Barni, M. Corsini, A. de Rosa and A. Piva. 2003. *ArtShop: an art-oriented image-processing tool for cultural heritage applications*, “The Journal of Visualization and Computer Animation”, 14(3): 149–158.

Carneiro, Gustavo, Nuno Pinho da Silva, Alessio Del Bue and João Paulo Costeira. 2012. *Artistic image classification: an analysis on the PRINTART database*, in: Andrew Fitzgibbon, Svetlana Lazebnik, Pietro Perona, Yoichi Sato, Cordelia Schmid (ed.), *ECCV 2012, Part IV. LNCS*, Heidelberg: Springer, 7575: 143–157.

Carneiro, Gustavo. 2013. *Artistic image analysis using graph-based learning approaches*, “IEEE Transactions on Image Processing”, 22(8): 3168–3178.

Carneiro, Gustavo. 2011. *Graph-based methods for the automatic annotation and retrieval of art prints*, “ICMR ‘11 Proceedings of the 1st ACM International Conference on Multimedia Retrieval, April 17–20, Trento, Italy”, ACM: New York.

Ceynowa, Klaus. 2013. *The image is the record – Similarity-based image search for visual materials in digitized library collections: The approach of the Bavarian State Library*, paper presented at: IFLA WLIC 2013 – Singapore – Future Libraries: Infinite Possibilities in Session 202 – Art Libraries with Rare Books and Manuscripts, http://library.ifla.org/180/1/202-ceynowa-en.pdf [2.04.2016].

Chen, Qian and Gustavo Carneiro. 2015. *Artistic Image Analysis Using the Composition of Human Figures*, in: *Lourdes Agapito, Michael M. Bronstein, Carsten Rother* (ed.), *ECCV 2014 Workshops, Part I, LNCS 8925*, Springer Int. Pub., pp. 117–132.

Closer to Van Eyck: Rediscovering the Ghent Alterpiece, http://closertovaneyck.kikirpa.be/ [22.04.2016].

Eakins, John, Jean Brown, Jon Riley and Richard Mulholland. 2001. *Evaluating a Shape Retrieval System for Watermark Images*, in: Anna Bentkowska (ed.), *Digital Art History – A Subject in Transition: Opportunities and Problems*, CHArt Conference Proceedings, vol. 4, http://www.chart.ac.uk/chart2001/papers/noframes/mulholland.html [2.04.2016].

Eakins, John P., Jago M. Boardman and Margaret E. Graham. 1997. *Evaluation of a Trademark Image Retrieval System*, in: David Dagan Feng, Fuhui Long (ed.), *Proceedings of the information retrieval research, the 19th annual BCS-IRSG colloquium on IR research, Aberdeen*, UK: BCS Information Retrieval Specialist Group, pp. 177–187.

Elgammal, Ahmed and Saleh Babak. 2015. *Quantifying Creativity in Art Networks*, “Proceedings of the Sixth International Conference on Computational Creativity (ICCC 2015)”, pp. 39–46.

Experimental CBIR Systems (lecture notes), https://www.cs.auckland.ac.nz/courses/compsci708s1c/lectures/Glect-html/topic6c708FSC.htm [22.04.2016].

Flickner, Myron et al. 1995. *Query by image and video content: the QBIC system*, “IEEE Computer”, 28(9): 23–32.

Hermitage Museum Project at IBM Research, http://www.research.ibm.com/haifa///projects/software/hermitage/index.html [22.04.2016].

Holt, Bonnie, Ken Weiss, Wayne Niblack, Myron Flickner and Dragutin Petkovic. 1997. *The QBIC Project in the Department of Art and Art History at UC Davis*, “Proceedings of the ASIS Annual Meeting”, 34: 189–195.

Johnson, Richard C. et al. 2008. *Image Processing for Artist Identification: Brushwork in the Paintings of Vincent Van Gogh*, “IEEE Signal Processing Magazine”, 25(4): 37–48.

Kato, Toshikazu, Kurita Takio and Ayumi Sakakura. 1989. *Electronic Art Museum: Full Color Image Database with Visual Interaction on Color and Sketch*, “IEICE Tech. Rep.”, IE88-118, pp. 31–38 (in Japanese).

Knell, Simon. 2010. *The Shape of Things to Come: museums in the technological landscape*, in: Ross Parry (ed.), *Museums in a Digital Age*, 1.3, pp. 435–453.

Lee, Denis, Ron Barber and Wayne Niblack. 1994. *Indexing for complex queries on a query-by-content image database*, “Proceedings of 12th International Conference on Pattern Recognition”, Computer Vision & Image Processing, IEEE Computer Soc. Press, Los Alamitos, 1: 142–146.

Lombardi, Thomas. 2005. *The classification of style in fine-art painting. ETD collection for Pace University*, Paper AAI3189084.

Otal, Moreu H., Mark van Staalduinen, Pavel Paclík and Jan van der Lubbe. 2008. *Watermark detection in X-ray images from paper for dating artworks*, Proceedings of the Fifth IASTED International Conference on Signal Processing, Pattern Recognition and Applications (SPPRA ‘08), pp. 66–71.

Pioch, Nicolas. *Web Museum*, https://www.ibiblio.org/wm/about/ [2.04.2016].

PROFI: Perceptually-relevant Retrieval Of Figurative Image, project description, for the sixth framework programme FP6/2002/IST/C, 2004–2007, http://profi.cs.uu.nl/description/description.pdf [2.04.2016].

Rauber, Christian, Thierry Pun and Tschudin Peter. 1997. *Retrieval of images from a library of watermarks for ancient paper identification*, “Proceedings of EVA 97: Elektronische Bildverarbeitung und Kunst, Kultur, Historie”, Berlin.

Rauber, Christian, Peter Tschudin, Serguei Startchik and Thierry Pun. 1996. *Archival and retrieval for large image databases: application to an historical watermarks archive*, in: D. Tsichritzis (ed.), *Objects Applications*, University of Geneva, pp. 19–26.

Rewald, Sabine. 2000. *Paul Klee (1879–1940)*, in: *Heilbrunn Timeline of Art History.* New York, The Metropolitan Museum of Art, http://www.metmuseum.org/toah/hd/klee/hd_klee.htm [22.06.2017].

Riley, Jonathan K. and John P. Eakins. 2003. *Content Based Retrieval of Historical Watermark Images: I – tracings*, in: M.S. Lew, N. Sebe and J.P. Eakins (eds.), *Image and Video Retrieval: International Conference, CIVR 2002*, London, UK, July 18–19, 2002. Proceedings, Springer, pp. 253–261.

Riley, Jonathan K., Jonathan D. Edwards and John P. Eakins. 2003. *Content Based Retrievalof Historical Watermark Images: II – Electron radiographs*, in: Erwin M. Bakker (ed.), *Image and Video Retrieval: Second International Conference, CIVR 2003*, *Urbana-Champaign, IL, USA, July 24–25, 2003, Proceedings*, Springer Science & Business Media, pp. 131–140.

Saleh, Babak, Kanako Abe, Ravneet Singh Arora and Ahmed Elgammal. 2016. *Toward automated discovery of artistic influence*, “Multimed Tools Applications”, 75(7): 3565–3591.

Smith Bautista, Susana. 2016. *Museums in the digital age: changing meanings of place, community, and culture*, Lanham, Maryland: AltaMira Press, Rowman & Littlefield.

Stork, David G. 2003. *Color and illumination in the Hockney theory: A critical evaluation*, Proceedings of the 11th Color Imaging Conference (CIC11), Scottsdale, AZ, vol. 11, pp. 11–15.

Stork, David G. 2005. *Did Georges de la Tour use optical projections while painting Christ in the carpenter's studio?*, in: Amir Said and John G. Apolstolopoulos (eds.), *SPIE Electronic Imaging: Image and video communications and processing*, 5685: 214–219.

The 15cBOOKTRADE Project, http://15cbooktrade.ox.ac.uk [2.04.2016].

The Bernstein Memory of Paper project documentation, http://www.bernstein.oeaw.ac.at/ [22.04.2016].

The AD751 software tool site, http://www.bernstein.oeaw.ac.at/ad751/index.html [22.04.2016].

The Artiste project documentation, http://users.ecs.soton.ac.uk/km/projs/artiste/ [2.04.2016].

The Artstor database, http://www.artstor.org/ [22.04.2016].

The Az – Azulejo Research Network, http://redeazulejo.fl.ul.pt/redeazulejaria_en/default.aspx [22.04.2016].

The Collage database, http://www.resource.gov.uk/ [2.04.2016].

The Google Art project, https://www.google.com/culturalinstitute/project/art-project?hl=pl [22.04.2016].

The Planet Hunters, https://www.planethunters.org/ [22.04.2016].

The PrintART project, http://printart.isr.ist.utl.pt/ [22.04.2016].

The SHREW project, http://www.unn.ac.uk/iidr/research/wmarks/wmarks.html, fragments available via http://archive.org/web/ [2.04.2016].

The SWIC project, http://vision.unige.ch/demos.html, fragments available via http://archive.org/web/ [2.04.2016].

Vaughan, William. 1985. *The Automated Connoisseur: Image Analysis and Art History*, in: Peter Denley and Deian Hopkins (eds.), *History and Computing*, Manchester, pp. 215–222.

Vanrell, Maria, Fahad Shahbaz Khan and Joost van de Weijer. 2010. *Who painted this painting?*, in: *Proceedings of The CREATE 2010 Conference*, pp. 329–333.

Ward, Anette A., Margaret E. Graham, Jonathan Riley and Nic Sheen. 2002. *Enhancing a Historical Digital Art Collection: Evaluation of Content-Based Image Retrieval on Collage*, in: A. Bentkowska, T. Cashen and J. Sunderland (eds.), *Digital Art History? Exploring Practice in a Network Society*, CHArt Conference Proceedings, http://www.chart.ac.uk/chart2002/papers/noframes/ward.html [2.04.2016].

Ward, Anette A., Margaret E. Graham, Jonathan Riley, Eliot Ney and John Eakins. 2001. *Collage and Content-based Image Retrieval: Collaboration for enhanced services for the London Guildhall Library*. Presented at Museums and the Web 2001, Seattle, 15–17 March 2001, http://www.museumsandtheweb.com/mw2001/papers/ward/ward.html [2.04.2016].

Wolf, Thomas. 2015. *Image recognition and image similarity – CERL*, presentation submitted at Liber Conference, London 2015, http://www.liber2015.org.uk/wp-content/uploads/2015/03/2015-06-24-wolf_image-recognition.pdf [2.04.2016].

Zweig, Benjamin. 2015. *Forgotten Genealogies: Brief Reflections on the History of Digital Art History*, "International Journal for Digital Art History", 1: 38–48.

ANNA OLSZEWSKA, JOANNA GANCARCZYK

MUZEUM JAKO LABORATORIUM WIZUALNE? POWIĄZANIA KULTURY Z TECHNOLOGIĄ W DZIEDZINIE CYFROWEGO ROZPOZNAWANIA OBRAZÓW

Czy muzea oraz biblioteki naukowe spełniają funkcję laboratorium technologii informacyjnych? W artykule rozpatrzono historię najważniejszych projektów wykorzystujących cyfrową analizę obrazu do porządkowania kolekcji bibliotek i muzeów. Prowadzone badania miały na celu krytyczną ocenę współpracy muzeów i dziedzin technologicznych w tym zakresie. Wyniki mogą zostać wykorzystane w planowaniu tego rodzaju współpracy. Artykuł rozpoczyna dyskusja na temat projektów, w których muzea i biblioteki przyjęły rolę dostarczyciela danych wykorzystanych do testowania nowych metod analizy obrazu (np. systemy: SWIC, Collage, SHREW). Następnie zostały zaprezentowane przykłady współpracy, w której do porządkowania kolekcji muzealnych zastosowano gotowe rozwiązania technologiczne (i.e. QBIC, Artiste). Dalej przeanalizowano projekty podejmowane z inicjatywy samych bibliotek (BSB, Oxford Ballads Online, PrintArt) oraz przykład konsorcjum skupionego na specyficznym typie danych wizualnych (the Bernstein Project poświęcony historycznym filigranom).

Słowa kluczowe: kultura wizualna, cyfrowa analiza obrazów, muzeum, biblioteka