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Signal Processing for Art Investigation

Why should signal processors care about problems in cultural heritage? What can signal processing offer to the world of art scholarship and preservation?

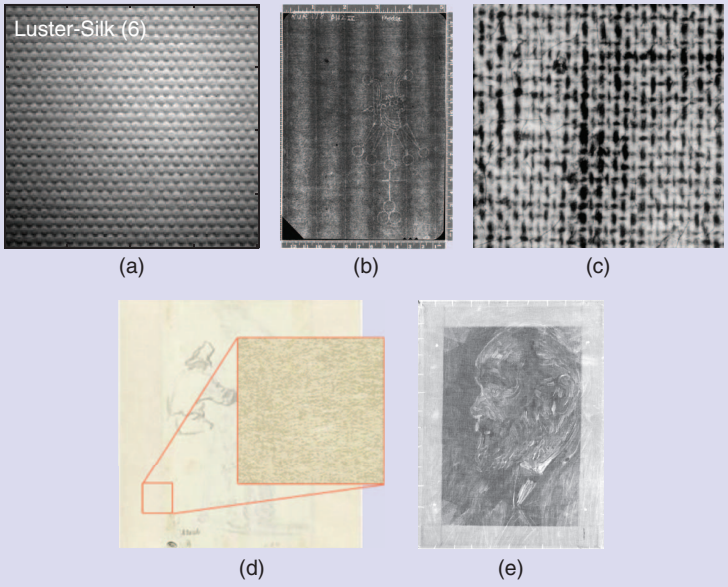
These complementary questions have motivated recent movement in our two communities—one composed of signal processors and art experts in the other—to collaborate and try to focus the signal processing technologies on underresolved problems of art investigation.

At the start of this century, a plenary talk [1] delivered at the 2001 IEEE International Conference on Image Processing divided the subjects of a two-decade long cross-disciplinary effort between a Paris technical university (ENST) and the French national conservation labs (C2RMF) into two broad categories: 1) archiving and consulting and 2) picture processing for the fine arts. The first category incorporates image acquisition and database access. The second includes image enhancement and restoration, crack network detection, multisource image fusion, color processing, and geometric analysis. Consider a different division of these topics into three groups: 1) image acquisition, 2) image manipulation, and 3) image feature mining. The topics of research in the 1980s and 1990s described in [1] give more attention to the first two of these groups than to the third.

IEEE Signal Processing Magazine (*SPM*) has recognized previously—with a special section "Recent Advances in Applications to Visual Cultural Heritage" in its July 2008 issue [2]—the growing interest at the start of this century in the nascent application of signal processing to art investigation. Following a vivid description of a wide range of tasks to be addressed in applying signal processing to the analysis of visual cultural heritage, six articles were grouped by the guest editors [3] into three themes: multispectral imaging, artwork analysis, and three-dimensional (3-D) digitization and modeling. By our division, this special section exhibits a balanced emphasis on all three groupings of image acquisition, manipulation, and feature mining.

The March 2013 special issue of *Signal Processing* devoted to "Image Processing for Digital Art Work" divides [4] its seven papers into two categories: artwork restoration tools (X-ray fluorescence, crack detection) or art piece analysis procedures (canvas weave analysis, painting stylometry analysis). Here the emphasis according to our grouping has shifted to image feature mining.

SURFACE ANALYSIS FOR IDENTIFYING ARTISTIC STYLE AND ARTWORK ORIGIN



[FIGS1] A number of articles in this special issue highlight the important role of texture and surface analysis in art investigations. (a) Abry et al. employ multiscale anisotropic texture analysis to facilitate classification of historical photographic prints; (b) Johnson et al. examine chain-line features to hunt for moldmates among Rembrandt's prints, which are papers made using the same mold; (c) van der Maaten et al. focus on thread-level canvas analysis from X-ray data of the canvas supports of grand master paintings such as those by Van Gogh, and thus facilitate dating and authentication; (d) van Noord et al. learn artists' styles by applying deep neural network to detailed texture and other visual stylistic features from artworks; and (e) Yang et al. discuss the advantages of two-dimensional synchrosqueezed transforms toward quantitative analysis of canvas weave.

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OBJECT RECOGNITION FOR MANAGING ART DATA

(a) (b) (c) (d)

[FIGS2] (a) Anwar et al. review the classification of ancient coins by recognizing reverse motif on coins; (b) Hu et al. outline an integrated system to facilitate the study of Mayan writing, with glyph analysis and retrieval playing an important role; (c) Srinivasan et al. discuss challenges of face recognition from Renaissance portrait arts to facilitate art historians in identifying the subjects in these portraits; and (d) Picard et al. present challenges and solutions for content-based image indexing of cultural heritage collections including a wide variety of artifacts such as this tapestry which may be assigned such labels as "landscape," "ornamentation," "river," "village," "water mill," and more.

ART ENHANCEMENT AND RESTORATION

(a) (b)

[FIGS3] (a) Lozes et al. examine graph signal processing approaches to cultural heritage applications, such as facilitating colorization of historical art pieces; (b) Pizurica et al. discuss inpainting and other digital image processing for the restoration effort of *The Ghent Altarpiece*.

A recent plenary talk [5] delivered at the 2014 IEEE International Conference on Acoustics, Speech, and Signal Processing describes three separate tasks in computational art history utilizing signal processing algorithms to match manufactured patterns in art supports. In another plenary addressing image processing for art investigation delivered in 2014, the majority of projects described also include tasks in the category of image feature mining [6]. All of these tasks fall in the category of image feature mining.

While early research in applying signal processing to art investigation emphasized image acquisition and image manipulation, various manifestations of image feature mining have achieved more prominence in the past decade as evidenced by the preceding citations providing successive indicators of the directions being taken in this growing field. The 11 articles in this special issue of *SPM* include studies of photographic paper classification, ancient coin classification, Mayan epigraphy analysis, 3-D color print graph signal processing, laid paper chain-line pattern matching, content-based image indexing, canvas weave analysis, crack detection for simulated in-painting, painting style characterization, and face recognition in portraits (see "Surface Analysis for Identifying Artistic Style and Artwork Origin," "Object Recognition for Managing Art Data," and "Art Enhancement and Restoration" for visual examples of these topics). All of these articles engage, to a substantial degree, in image feature mining. There is an enormous need in art history and conservation to locate, classify, identify, and measure features in multispectral and multidirectional images of artworks.

One barrier of entry into this field is access to images of sufficient quality and quantity of artworks. Therefore, for this special issue, the authors were requested to make the images they processed accessible to other researchers (when possible) to stimulate the exploration of new and improved solutions, and most have complied. With that added bonus, we welcome you to the modest beginnings of an emerging field that promises to offer many satisfying challenges and will require specialization of and advances in the tools and techniques of signal processing. To assist you in deciding which of the articles to use as your portal into this new domain full of ample, low-hanging fruit and many as yet undiscovered puzzles, we offer the summaries available at http://sigport.org/189.

Authors were encouraged to have a representative from the cultural heritage

community on their team, which is the case for most of the articles in this issue. Such cross-disciplinary collaborations are difficult. The art expert needs to acquire an appreciation of the range and limitations of the signal processor's tools so useful, viable, novel tasks can be identified and addressed. The signal processing experts must learn to describe their skills without resorting to the language of deep mathematics, and to appreciate the intellectual depth of the art expert achieved without directly resorting to computational tools. Both sides are facing new ways of thinking and conducting research. Of course, all of this makes the challenge that much more appealing to us. So it goes...

MEET THE GUEST EDITORS

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