18 The Digital Imaging of Watermarks

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Abstract

The traditional methods used by music historians for imaging watermarks are problematic. Freehand tracing is inherently prone to inaccuracy, the Dylux method often seems ineffective with musical manuscripts, and beta-radiography has become prohibitively expensive. After outlining the characteristics that should ideally be possessed by any new method of watermark imaging, my paper goes on to present the results of a simple experiment in creating digital images of watermarks, using a scanner equipped with a transparency adapter and manipulating the resulting images with Adobe *Photoshop*. Even this simple experiment is shown to give very good results. I then consider how this method might be adapted for use in the field, and I consider possible refinements to the method, drawing on the paper of Stewart, Scharf, and Arney in the *Journal of Imaging Science and Technology* (1995).

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18.1 Desiderata for a Method of Watermark Imaging

The evidence of paper-studies, and of watermarks in particular, has proven to be immensely useful in the investigation of the dating and provenance of musical manuscripts and prints, and it has also shed light on compositional process, on the biographies of composers, and on the distribution of their music.

The methods used by music historians to make images of watermarks are, however, still in general quite crude. Most scholars continue to trace watermarks by hand, and few know how to do that properly. Of the alternatives to tracing, beta-radiography has gained some currency among music historians, but it is growing increasingly impractical, largely because of escalating costs.

A method for making images of watermarks in music paper should have the following characteristics:

1. It should produce images of a quality sufficient for direct and unambiguous comparison of watermarks from different sources. When I speak of watermarks here, I am referring specifically to the complex of watermark, countermark, chainlines, laid lines, and (if present) the sewing dots of a pair of molds used in the making of handmade laid paper.

2. The images should contain minimal interference from notes, staff lines, and text on either side of the paper.

3. The method should allow the image of the entire watermark of the original sheet to be reconstructed with relative ease.

4. Images should be stable, robust, and easy to file and retrieve, and they should require a reasonable amount of storage space.

5. The system for making images of watermarks should be easily transportable, and designed for use in remote archives with limited resources.

6. The system should be affordable, and, if possible, it should use off-the-shelf, readily available components.

7. Ideally, the images should be of a quality suitable for publication, and, in any case, they should be suitable for use in a Web-based database of paper-types.

18.2 Approaches to the Imaging of Watermarks

David Schoonover, in an excellent article in the collection *Essays in Paper Analysis* (Schoonover 1987), describes four principal methods for making images of watermarks.

1. In tracing, the paper with the watermark is placed over a back-light, and a piece of tracing paper is placed over the watermarked paper. The watermark is traced freehand with a soft lead pencil. This method is cheap, and the equipment (a back-light, tracing paper, and pencils) is eminently portable. However, the quality of the image is only as good as the researcher's muscular control and hand-eye coordination (which is to say, often not very good), and at best, the images are prone to inaccuracy, incompleteness, and distortion. Watermarks in thick, dark or heavy paper, or in paper that is heavily covered with writing, may be difficult or impossible to trace.

2. The Dylux method produces a contact image of a watermark using Dylux paper manufactured by DuPont. Images can be made in a lighted room, using a fluorescent lamp for the exposure and an ultraviolet lamp for developing the image. The resulting image looks rather like a blueprint. The Dylux method is widely used by literary historians, by historians of the book and of publishing, and in the investigation of historical documents. The paper and equipment is relatively cheap. It has not been so widely used by music historians, perhaps because the thickness of the paper used for music and its formats (upright and oblong quarto from large original sheets) make the technique relatively impractical.

3. Ilkley Technique is another contact method, using large sheets of photographic film, exposed with a normal desk lamp. The images of the watermark can be very good, but are obscured by anything on the surface of the paper. It is not widely used.

4. Beta-radiography has been the imaging method of choice for about the past thirty years or so. Again, photographic film is placed in direct contact with the paper, but in this case it is exposed with a source of carbon-14 radiation. The resulting images are of very high quality, and they have the important advantage of not recording the ink on the surface of the paper. Disadvantages, unfortunately, are many. Most important, radiation sources have become prohibitively expensive, not only for individuals, but

even for libraries. The method is not practical for field work, as it requires a darkroom. Although the level of radiation is extremely low, many libraries will not allow it on grounds of safety. Transporting radiation sources across national boundaries could obviously present severe problems. (I have recently seen a reference to a new technique using very low-level X-rays, which may have the potential to address the problems of cost and safety.)

18.3 Digital Imaging

At the First International Conference on the History, Study, and Function of Watermarks in Roanoke, Virginia (October 1996), participants were given a brochure prepared by the Italian group Fotoscientifica. This brochure included spectacular digital color images of watermarks. They were, it seems safe to say, the best watermark images that any of us had ever seen. Particularly impressive was a fold-out spread (a sort of "Watermark of the Month") showing a full-sheet watermark assembled from the images of eight separate leaves in octavo format taken from a printed book. Although, on close inspection, this assembled image proved to be slightly "fudged" (at least one of the pictured leaves did not fit properly with the rest of the mold), the results were nevertheless impressive enough to suggest to me and to others at the conference that digital imaging of watermarks had tremendous potential.

The Italian method is proprietary, and its details were not spelled out in the brochure. However, it was clear that the quality of the equipment used and the resolution employed were excessive: the images were of extraordinarily and unnecessarily high resolution. It seemed to me at the time, however, that images of sufficient resolution and quality for use in manuscript analysis could probably be made with relatively inexpensive, off-the-shelf equipment.

In October 1998, I was able to make preliminary experiments in this direction at Louisiana State University, with the assistance of Charles F. Thomas (at that time Interim Curator of the Louisiana and Lower Mississippi Valley Collection in Hill Memorial Library at Louisiana State University), his graduate assistant Ji Huizhen, and Jim Zietz, Assistant Director of University Relations and the campus authority on Adobe *Photoshop*.

We decided to begin by testing direct scans of manuscripts. For this, we used a UMAX Powerlook scanner with a transparency adapter, which allowed us to make both transmissive and reflective scans of a manuscript. I located a suitable test manuscript in the Hill Library: a set of nineteenth-century manuscript parts for an Adagio and Polonaise for Clarinet and Piano by the German clarinetist and basset-horn player Iwan Müller (1786-1854), shelfmark 788.6 M88a.

The format of the manuscript is upright folio, and the watermarks are, as a result, in the center of the leaf, which makes the manuscripts easier to manipulate, and which allowed us to avoid, for the moment, the problem of "reassembling" the watermark from pieces on different leaves. The watermark and countermark are both present in the manuscript, and both are relatively clear, complex designs. However, the paper is low in quality and relatively dark. Furthermore, the manuscript is densely written in iron-gall ink that is still almost black. The low quality of the paper and the density of the ink insured that our experiment would be fairly realistic.

The piano part of Müller's piece occupies five leaves, consisting of two nested bifolia with a single leaf at the center. For our experiments, we concentrated on the outer bifolium, which contains both the mark and countermark of one mold. We scanned folios 1^{v} and 5^{r}, the mold-side of the outer bifolium.

For each leaf, we made both a transmissive scan and a reflective RGB scan at 300 dpi (see Figures 1a and 1b, showing the scans of f. 5^{r}). We manipulated these images using Adobe *Photoshop* 5.0 on a Macintosh G3 desktop system. Scans were made with the mold side of the paper facing the transparency adapter. The music appears upside down because the copyist used the paper with the watermarks inverted.

As is evident from Figure 1b, the transmissive scan already gives a quite good image of the watermark, which is, however, obscured by the staff lines, notes, and handwriting on both sides of the paper. In fact, it may be more accurate to say that the staff lines, notes, and handwriting interfere with our perception of the pattern of the watermark. The method that we devised to deal with this problem in effect simply sets the color of the ink in the image close to the background color, in order to reduce this perceptual interference, so that the pattern of the watermark will be more evident by contrast.

In order to do this, the transmissive and reflective scans were layered in *Photoshop*. The *transmissive* scan became the background layer. The *reflective* scan was inverted to a negative, and then layered directly above the transmissive scan. We created both a color and a grayscale image from the combination of these two layers: in the color image, the opacity of the inverted reflective scan was set to 30%, and for the grayscale image, only the red channel of the reflective scan was used, with the opacity set to 40% (these settings were derived by trial and error).

Figure 1a. Reflective scan, f. 5^{r} of the piano part of Iwan Müller's Adagio and Polonaise for Clarinet and Piano, Louisiana State University, Hill Memorial Library, shelfmark 788.6 M88a. [The music appears upside down in order to show the watermark rightside up. This was how the copyist used the paper.]

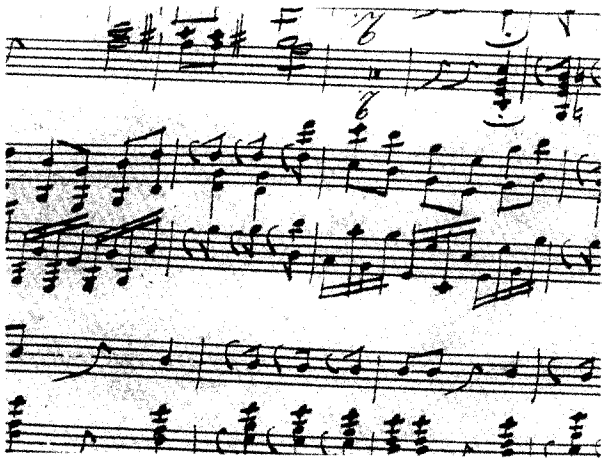


Figure 1b. Transmissive scan [forming the background layer], f. 5 ^{r} of the piano part of Müller's Adagio and Polonaise for Clarinet and Piano.

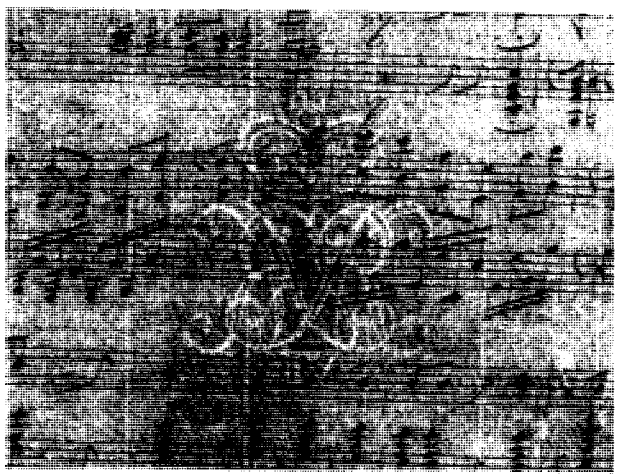


Figure 2a. Combined color image of the reflective and transmissive scans of the watermark in f. 5[r] of Müller's Adagio and Polonaise for Clarinet and Piano.

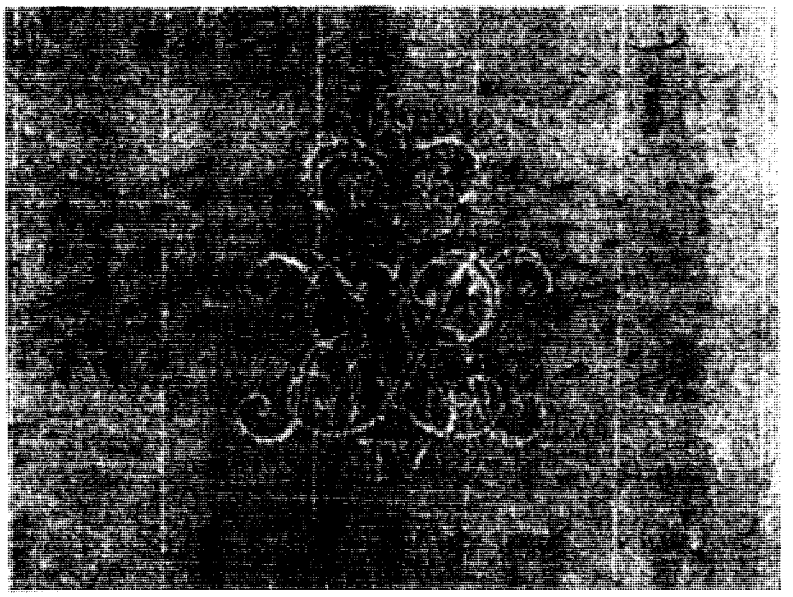
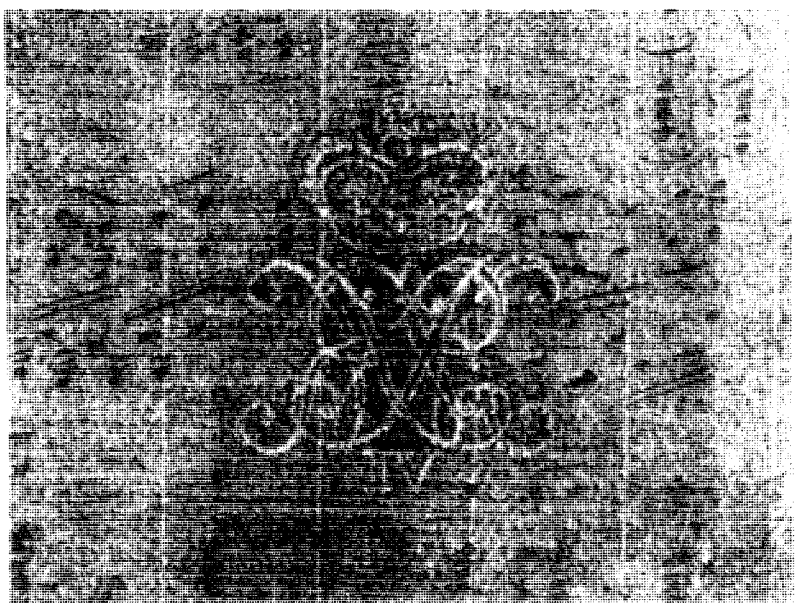


Figure 2b. Combined grayscale image of the reflective and transmissive scans of the watermark in f. 5[r] of Müller's Adagio and Polonaise.



The combined color image is shown in Figure 2a, and the combined grayscale image is shown in Figure 2b.

We followed the same procedure with the countermark in folio 1 of the piano part of Müller's piece (Figures 3a-d). In both cases, the grayscale images seem somewhat clearer.

Figure 3a. Reflective scan, f. 1^{v} of the piano part of Müller's Adagio and Polonaise for Clarinet and Piano.

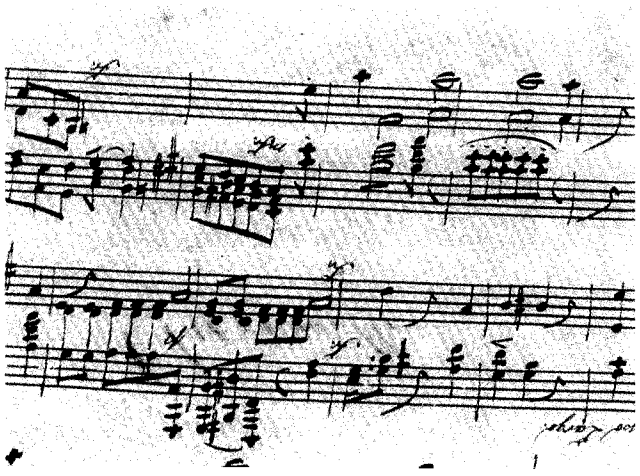


Figure 3b. Transmissive scan, f. 1^{v} of the piano part of Müller's Adagio and Polonaise for Clarinet and Piano.

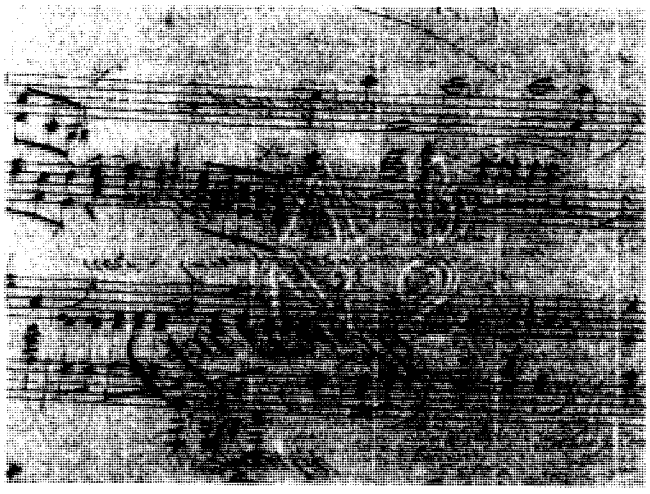


Figure 3c. Combined color image of the reflective and transmissive scans of the countermark in f. 1 of Müller's Adagio and Polonaise for Clarinet and Piano.

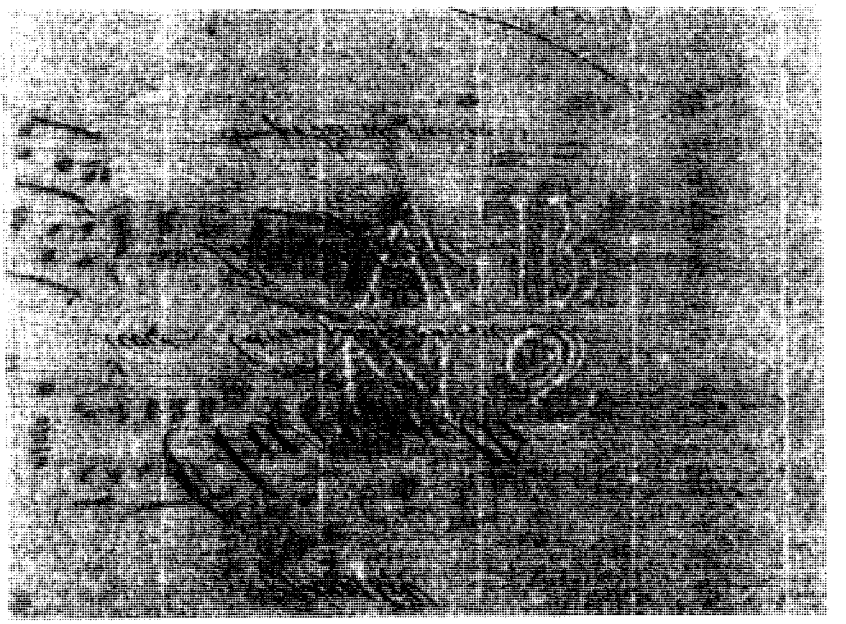
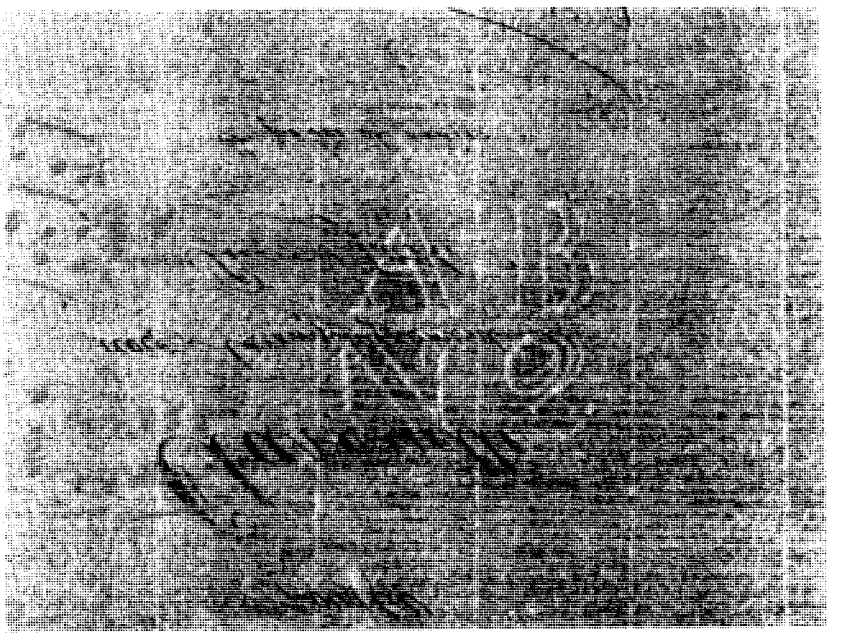


Figure 3d. Combined grayscale image of the reflective and transmissive scans of the countermark in f. 1 of Müller's Adagio and Polonaise for Clarinet and Piano.



It is evident that these images, even using this relatively crude method, are better than usable. The patterns of the watermarks, the chain lines, and the laid lines are all very clear. The method is simple, and it uses off-the-shelf hardware and software. The equipment required for use of this method in the field would be a flatbed scanner with a transparency adapter, and a laptop computer sufficiently powerful for imaging work, with scanning software, *Photoshop* or equivalent software for image manipulation, and plenty of disk storage. This equipment, while somewhat bulky, would be transportable, and, while expensive, would undoubtedly be cheaper than a radiation source. The method is practical for use in the field and does not require a darkroom.

We have not yet tried to assemble the component images into the image of a full-sheet watermark (partly because at the time we did not have access to a suitable manuscript), but this assembly ought to be relatively straightforward. With some minor adjustments, these images would be suitable for publication.

There are a number of ways in which the technique might be improved, and there are a number of problems that we have not yet attempted to deal with. These are discussed below.

18.4 Discussion and Directions for Further Research

18.4.1 OR vs. AND Strategies

There is not yet much literature on the digital imaging of watermarks. While preparing the talk upon which this paper is based, I ran across an article (Stewart, Scharf, and Arney, 1995). The authors were at that time all connected with the Center for Imaging Science at the Rochester Institute of Technology (Arney is the director of the center). Their article discusses two broad approaches to watermark imaging which the authors call the "OR Strategy" and the "AND Strategy."

The *OR Strategy* is the cruder of the two, and corresponds more or less directly to our experiment at Louisiana State University: the digital images are analyzed (or "segmented") to identify component elements within the image, the ink color is identified, and it is set to a color close to overall average background of the paper. In other words, the image is segmented

according to whether a particular pixel is ink OR watermark OR background.

As the authors point out (and as our test images demonstrate), "the nonuniformity of the paper makes it impossible to segment all of the ink without also losing some of the watermark and laid lines" (Stewart, Scharf, and Arney 1995: 263).

Stewart, Scharf, and Arney were able to improve their images from this method somewhat by using what they call "two-dimensional image segmentation," which allows a distinction between ink on the front and on the back side of the paper.

However, the authors have shown that superior results can be achieved using what they call the "AND Strategy." As they explain, ". . . the thesis behind the AND strategy is that each pixel may contain information about the ink AND the watermark. The objective of the AND strategy, then, is not to classify a pixel but to separate the information content of each pixel into its component parts" (Stewart, Scharf, and Arney 1995: 264). They attempt to do this by constructing two different mathematical models of the optics of ink and paper.

Space does not permit a detailed outline of these models, and the reader is referred to their article. To summarize: the first, the Beer-Lambert model, treats the paper as a Lambertian reflective surface and the ink as a transparent covering that absorbs light according to the Beer-Lambert law. Although the theory of this approach is rather complicated (at least for scientifically-challenged musicologists), the resulting equation is remarkably simple.

For each pixel as defined by its two-dimensional coordinates (x, y):

$$T(x, y) = \frac{T_i(x, y)}{R(x, y)^n}$$

In effect, this equation simply means that each pixel of the transmissive scan (T_i) is divided by each pixel of the reflective scan $R(x, y)$, raised to some power (n) to produce the Beer-Lambert metric $T(x, y)$. By trial and error, the authors have determined that the procedure works best when n is set to 1.2.

This model, although it produces very good results, has one significant weakness. A very large proportion of historical documents written on handmade laid paper were written with iron-gall ink. This ink is acidic and attains its permanence, in part, by eating into the paper. In other words, the ink is not sitting on the surface, as is assumed in the Beer-Lambert model.

Stewart, Scharf, and Arney discuss a second optical model, the "Kubelka-Munk" model, which takes this factor into account, at the cost of a much more complicated formula for the calculation of pixel values, which is best implemented through a look-up table. It does, however, give extremely good results.

The extent to which either of these more refined models could be implemented with off-the-shelf software remains to be investigated.

18.4.2 File Size vs. Resolution Needs

The uncompressed raw images from our tests are both slightly over 6 MB in size. The combined color image is roughly 12 MB, and the combined grayscale image is 2 MB. The sizes of these files are relatively modest by imaging standards, but are probably too large to be practical in a database that may include thousands of images. It seems clear that the level of resolution used in our experiment was much higher than would be necessary for most scholarly purposes. If the resolution were decreased, the sizes of the files could be substantially reduced.

18.4.3 Methods of Image Comparison

We did not make more than superficial attempts to deal with the problem of image comparison. We did attempt to overlay two of the combined images, and it seems that such direct superimposition through the layering of images could work, although various problems arise.

Another approach might be to use digital tracings. I attempted to trace one of the watermark images shown here, using a WACOM tablet. This method has the disadvantages of all freehand tracing (I found it rather more awkward and imprecise than tracing an actual watermark, but this impression may have simply reflected my inexperience). Jim Zietz has suggested that highly accurate tracings might be possible using the

facilities of a program such as Adobe *Illustrator*. This idea seems worth pursuing.

18.4.4 Dealing with Bound Manuscripts

Flatbed scanners are really only practical for material that is not bound. Since music historians must often deal with bound manuscripts, we need to find alternative technical routes to achieve the same end. One approach might be to use a digital camera. However, at present, it is not clear that digital cameras would be practical, given the trade-off between cost, resolution, and storage capacity. However, the terms of that trade-off are obviously changing quite rapidly.

Another approach might be to scan normal color slides that were created in a way similar to the scans described here. This method would have the disadvantage that the resulting images could not be processed in the field. Either of these photographic methods would require consistency and high quality in the back-lighting.

18.5 Additional Advantages of Digital Imaging for Manuscript Studies

Digital images resulting from any of the methods outlined here could potentially be used for many other purposes: for example, they could be used for the investigation of copyist hands, the comparison of rastra, or even the enhancement of obscured, erased, or cancelled passages. The multiple utility of the images is yet another potential advantage of such digital methods. The prospects for developing an efficient and cost-effective way to make such images in the field seem excellent.

References

Edge, Dexter (2000). "Mozart's Viennese Copyists." Ph.D. dissertation, University of Southern California. See especially Chapter 3, "The Analysis of Manuscript Music and Musical Handwriting."

Schoonover, David (1987). "Techniques of Reproducing Watermarks: A Practical Introduction" in Stephen Spector, ed., *Essays in Paper Analysis* (Washington: Folger Books), 154–167.

Stewart, David, Robert A. Scharf, and J. S. Arney (1995). "Techniques for Digital Image Capture of Watermarks," *Journal of Imaging Science and Technology* 39, 261–267.