

# Digital Image Capture of Musical Scores

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## ABSTRACT

Musical scores have small details and complex markings, and are difficult to digitally capture and deliver well. All capture decisions should be made with a clear idea of the purpose of the resulting digital images, but master images must be flexible enough to fulfill unanticipated future uses. In order to provide a framework for decision-making in musical score digitization projects, best practices for detail and color capture are presented. Recommendations for file formats for archival storage, web delivery and printing of musical materials are presented.

## 1. INTRODUCTION

Music information retrieval research deals with resource discovery. However, the quality of the data itself is a critical part of the retrieval system, as content-based retrieval cannot work on inferior content. Musical scores are difficult to properly digitally capture and deliver for several reasons. They contain small details such as staff lines, dots, and bars that are essential to the meaning of the notation. They come in a wide variety of formats (printed and manuscript) and sizes. This paper is intended to provide an overview of the decisions that must be made when undertaking a musical score digital imaging project and provide some best practices for making these decisions.

## 2. THE PURPOSE OF SCANNING

The first step in planning any imaging project is to determine the purpose of image capture. Some formats, such as original manuscripts, rare imprints, and pages with important pencil markings or annotations, should be captured with the intent of reproducing the current appearance of the page as is. For many other formats, the current condition of the pages is not important, but instead the intent is to capture only the musical content contained within. The guidelines below offer advice on two types of capture: artifactual and content-based. Some imaging projects focus on capturing watermarks on the paper, but this will not be covered here [a][1][2][3].

For rare and fragile materials, analog capture on film may be a better option than digital imaging, as digital cameras do not yet perform as well as flatbed and film scanners. Generally 4"x5" color film is most suitable for this purpose [b].

## 3. MASTER FILE SPECIFICATIONS

### 3.1 Resolution

Musical notation must be scanned at a resolution sufficient to capture all *significant* detail. For a collection with little variation in print size, it may be appropriate to apply a formula to determine

the minimum capture resolution based on the stroke width of the smallest detail [4]. We have found this smallest detail is generally the white space between beams. 3 pixels per detail, rather than 2 pixels, is required for successful Optical Musical Recognition (OMR) with the forthcoming Gamera software. [5]

However, this approach presents some problems. Details in musical notation are consistently smaller than 1mm, requiring specialized measuring equipment. Also, few collections are homogeneous, which would require resolution calculation for each item, adding a great deal of time to the capture process.

For most projects it may be more practical to simply capture all images at the same resolution. Our tests have found that 600dpi is sufficient to capture all significant detail for most printed musical notation, as seen in Figures 1 and 2, where the 600dpi scan more adequately renders the ledger line and the sharp sign. 600dpi will capture detail as small as .005 in (.027mm) with 3 pixels. Our preliminary studies show that going above 600dpi does not offer much advantage for the purpose of viewing, printing, or OMR, even for extremely small notation. However, testing with specific hardware and materials is required to develop a final resolution specification for any given project.



Figure 1. 300dpi small detail.



Figure 2. 600dpi small detail.

### 3.2 Color Reproduction and Bit Depth

Most printed musical scores do not use color. 8-bit or higher grayscale capture of these is most appropriate. Sheet music covers, original manuscripts, and other color pages should be captured in 24-bit RGB. If the purpose of capture is both to represent the page as an artifact and to gain a file appropriate for OMR, 12-, 14-, or 16-bit per channel capture may be needed.

It is essential that all devices in the imaging system, including scanner, monitor and printer (if printed output is desired), be characterized and managed via International Color Consortium (ICC) profiles [c]. Locally-created ICC profiles for each device are preferable to generic profiles [d]. Color management with ICC profiles, while not perfect, is the best current solution to the problem of accurate tonal capture. Scanning for artifactual purposes is then simply capturing the item in a fully calibrated system with no manual adjustments. Use of ICC profiles is also preferred for content-based capture to ensure that the visual image the operator is viewing when making adjustments is accurate.

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For content-only capture, automatic or manual tonal adjustments may be desirable in order to maximize the contrast between the musical notation and background of the page. Pages should have completely filled-in note heads, solid staff lines, and clean white space between lines when viewed at 100% magnification. Deskewing and sharpening are also options.

### 3.3 Master File Formats

Imaging best practices to date have almost unanimously advocated uncompressed TIFF for storage of master files [e]. However, the TIFF specification is a de facto rather than a true standard. The PNG format may be an emerging replacement for TIFF for this purpose [f]. PNG has the capability to store all relevant information captured according to these guidelines, and as such would be technically suitable for a master file format for musical score images. PNG uses lossless compression, and compressed PNG files are significantly smaller than uncompressed TIFF files. It may be some time before it is clear whether the digital library community as a whole accepts PNG for this purpose.

### 4. WEB DELIVERY

For web delivery, only JPEG, GIF, PNG, and PDF are supported by majority of web browsers with common plug-ins. Thus formats such as TIFF and DjVu [6][g] are not currently appropriate for this purpose. Delivery by single page file formats such as JPEG, GIF, and PNG requires a page-turning mechanism for navigation. While the PDF format includes this functionality, it was not designed primarily for navigating raster image files, so the file sizes of full musical scores in PDF format are prohibitively large.

Digital imaging projects generally create images for web viewing based on a fixed pixel size. However, for musical notation, this approach must be abandoned in favor of one that ensures all significant detail is visible. For this reason, use of thumbnail images may not be necessary. Grayscale or color images at 100-200dpi (based on original page size) generally display all relevant detail on the screen, as seen at <<http://www.dlib.indiana.edu/~jenlrile/ismir2002/webdelivery/>>. In grayscale, JPEG images at medium-high to high quality levels are smaller than GIF files, and do not show obvious compression artifacts. File sizes are similar for JPEG and PNG, but PNG files decompress faster [h].

### 5. PRINTING

Score pages intended for use in practice or performance must be printable. Ideally, a multi-page file format would be used, but PDF, DjVu, and multi-page TIFF all present size or accessibility problems. For laser printing, bitonal TIFF, GIF, and PNG all provide similar results at 250-400dpi [i]. For lower resolutions in this range, bitonal PNG files are smaller, while at higher resolutions, CCITT Group 4 compressed TIFF files are smaller, as shown in Table 2.

Table 2. Average file size for 8.5"x11" bitonal images.

	PNG	TIFF (Group 4)
800dpi	329 KB	192 KB
400dpi	183 KB	146 KB
250dpi	90 KB	96 KB
200dpi	64 KB	71 KB
100dpi	25 KB	38 KB

### 6. CONCLUSION

Consistent and useful information retrieval depends heavily on the presence of adequate data. The overarching philosophy of capturing and presenting to the user all relevant data in the source material should guide digitization decisions. These guidelines are

based on current best practices in archival digital imaging, adapted to suit the unique capture and delivery requirements of musical notation.

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### 8. NOTES

- [a] Watermarks may be obtained by tracings, transmitted light photography, photosensitive paper technique (Dylux); beta radiography, or microfocus radiography. Image processing combining reflective and transmissive scans may offer inexpensive and relatively accurate results.
- [b] Ilford's Ilfochrome Micrographic film has an estimated life expectancy of over 300 years. <<http://www.microcolour.com/mci03.htm>>
- [c] The ICC's home page is at <<http://www.color.org/>>.
- [d] Software packages to perform profiling on your own devices are commercially available, such as those from Monaco Systems <<http://www.monacosys.com/index.html>>.
- [e] NARA <<http://www.nara.gov/nara/vision/eap/digguide.pdf>> and LC <<http://memory.loc.gov/ammem/formats.html>> have taken the lead in documenting best practices for digital imaging.
- [f] PNG (ISO/IEC 15948) is currently under publication.
- [g] DjVu holds promise in this area, as it was designed for raster image compression. Files are extremely small, and as the format becomes more pervasive DjVu may become a practical option.
- [h] Browsers not supporting PNG are now extremely rare: <<http://www.thecounter.com/stats/2002/April/browser.php>>.
- [i] See <<http://www.dlib.indiana.edu/~jenlrile/ismir2002/print/>> for sample images for printing.

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