SCORE Staff Placement

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This document provides a detailed analysis of the SCORE editor's (version 4.01000-555) staff placement in Encapsulated PostScript (EPS) output, and Section 0 demonstrates how to calculate exact staff placements within bitmaps converted from these EPS files. Analysis of the printing method in the SCORE editor consists of two primary stages: continuous-space vector graphics layout, and then quantization processing. Quantization in turn can be split into two sub-types: 4000-DPI quantization imposed internally by SCORE when writing EPS files, and the rendering-space quantization (with a focus on 600 DPI) related to stroke-width adjustment used to create uniformly thick staff lines when converting vector graphics into bitmapped images. Modeling the two quantization types allows for pixel-level localization accuracy for staff lines within bitmapped conversions from SCORE EPS files. This model can be used to accurately locate staff lines in bitmaps using only SCORE PMX data and page margin information, without referencing the derived bitmap. By extension, pixel-level localization of other graphical objects such as barlines can be implemented as well, which could for example be used to highlight measures in images of the notation.

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1 Overview of SCORE PMX data for staff objects.

SCORE represents graphical objects as lists of floating-point numbers. Each object stored in a data file, or internally in memory, is represented explicitly on the page using these numbers which are called parameters. "Parameter one" is the name of the first parameter, "parameter two" for the second number, and so on. These are usually abbreviated as P1, P2, P3, etc.[1] The positions of numbers in the parameter list indicate their meanings. When the list is shorter than a particular parameter number, that parameter's value is implicitly zero. Note that a zero-valued parameter can also indicate a default setting should be used. For example if P6=0 for staff lines, this means to use 200 for this parameter.

P1, P2, P3 and P4 for any object in SCORE have consistent meanings. P1 indicates the graphical object type. Staff lines are objects where P1=8, notes on the other hand would have P1=1. P2 indicates the staff to which the object belongs. There are default positions on the page for each staff, so this value also influences the vertical placement of objects on the page. For example if the object data starts "3 7", this means that the object is a clef (P1=3), and it is on staff #7 of the page (P2=7).

P3 controls the horizontal position of an object on the page. For items with a left and right end, P3 is the position of the left end, and P6 controls right end of the object. The horizontal units are not physical, but instead range from 0.0 at the left margin to 200.0 on the right margin. When printing at the default scaling, the physical length from P3=0 to P3=200 is 7.5″ (7.5 inches). When scaling the music by 50%, the physical length from 0 to 200 would be 3.25″.

P4 describes the vertical position of an object. For staves, P4 controls the vertical offset of the staff from its default position on the page. The vertical offset is also controlled by the vertical-scaling value stored in P5 of staff objects. The product P4 * P5 controls the actual vertical offset from a staff's default position on the page (excluding page scaling), so the vertical offset (P4=1, P5=1) is equivalent to the physical offset generated by the parameter pair (P4=0.5, P5=2).

Other parameters for staves are not particularly important for staff positioning since they are not used often in standard 5-line staff printing. These extra parameters will not be considered in the following analysis:

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[1] SCORE's parameter terminology and data structure are derived from Music V, created by Max V. Mathews in the late 1950's. This data organization also extends into CSound, which is the modern instantiation of Music V:
http://www.csounds.com/chapter1

[2] PostScript printing units are in points, so most of the physical length units in this docu-
http://www.csounds.com/chapter1

- P7 indicates how many staff lines are displayed (starting with staff line 1 at the bottom of the staff). If P7=0 then use the default setting of 5 lines. P7=−1 will make the staff invisible (zero staff lines). If P7 is a 3-digit number, then the 100's digit indicates which staff line on the standard 5-lined staff should be the bottom of the displayed staff, and the other two digits indicate how many staff lines. For example "304" means that the bottom line would be positioned where the 3rd (middle) line of the 5-line staff would normally be placed, and there are 3 lines above this line (for a total of 4 lines).
- P8 is used to indicate the distance from the bottom of the bottom staff on the page (P2=1) to the bottom of the bottom staff on a separate SCORE page file that is to be placed above the current page to construct a full score (used for splitting very large scores across multiple pages).
- P9 is used to store an instrument number. This information is useful for extracting parts from a full score, where the parts may drop out on systems where they are resting.
- P10 is an alternate method of positioning staves vertically (as opposed to the P2/P4/P5 method described below. A non-zero value in P10 indicates the distance from the bottom of the staff 1 to the bottom of the current staff in units of inches or centimeters (the measurement unit will be given explicitly in binary SCORE .MUS files, but is lost when saving SCORE data to ASCII PMX files). Note that P4 values are ignored if P10 values are non-zero.
- P11 controls the thickness of staff lines and the default thickness for ledger lines. Ledger lines are two pixels (based on the target print resolution) thicker than staff lines by default (unless P5 < 0.7, or the ledger lines are associated with a grace note). The thickness of ledger lines is controlled independently from the staff thickness by altering P16 for notes (P1=1).
- P12 has no printing purpose. It is used to hide the staff number in the SCORE editor's display window.

Further details about staff parameters can be found in the SCORE reference manual (version 3.0). Additional parameters may be defined for the Windows version of SCORE (starting with P13).

"PMX" is a command in the SCORE editor that saves all objects on the page to an ASCII text file. Typically .PMX will be the file extension used to distinguish from the binary data of .MUS/.PAG files, or text-based macro files which can include PMX data. "Parameter MatriX" is the meaning of the abbreviation PMX, since the data looks like a two-dimensional matrix of numbers. In the resulting text file each line (except for text objects and embedded PostScript objects which include a second line of plain text) represents an object as a list of numbers separated by one or more spaces (but not tabs). Figure 2 shows example PMX data for a page of music containing only staves and some text. Appendix V starting on page 88 contains a long example listing PMX data for a full page of music notation.

PMX and other text-based macro data files can be read into the SCORE editor using the REad command. In contrast, binary SCORE data files must be loaded into the editor with the Get command. PMX data has nearly equivalent content to the binary .MUS/.PAG files. The only difference is that the binary file format for PMX data also stores the unit (inches or centimeters) that is needed for certain parameters (such as P10 for staves). Note that musical objects can be sorted in any order in PMX/MUS files, not necessarily in time or spatial order. The order of objects in a file typically represents their print order (important when printing objects in color), but the Windows version of the SCORE notation editor adds an extra parameter for the printing order that overrides the data order in memory or a file.

2 SCORE printing variables

In order to determine the position of staff lines on a page, several variables are specified at print time. These variables are *not* stored within the SCORE data file describing a page of music (MUS or PMX formats). Instead these variables are set from the print menu, or they can be loaded from a separately stored text file as shown in Figure 1.

- The **SIZE** print setting controls the scaling of music on the page. 1.000 is the default size; 0.5 will cause the music to be displayed at 50%, 2.0 will display at 200%, etc. Staff lines will be 7.5″ (540pt) long when the staff is 200 horizontal SCORE units long and the SIZE variable is set to one.[2] If the size is 0.5, full-length staff lines will be 3.75″ long, and if the size is 2.0, full-length staff lines will be 15″ long. Note that the SIZE value does not scale the entire page. Margins offsets (see next parameter below) are applied first to move the origin from the bottom left bottom corner of the page to the OFFSETS position before the SIZE parameter is applied to scale the music's size.

```
OUTPUT          LPT1:
ROTATE          No
SIZE            1.000
PAPER           LTR
OFFSETS         .50     .75
FREEZE          No
RESOLUTION      600
LINE_width      4
HEADER/FOOTER   None
MIRROR          No
SETSTROKE       Yes
MANUAL_feed     No
SETPAPERTRAY    0
DESC            0
```

Figure 1: Default SCORE print parameter file settings.

- **OFFSETS** controls the width of the left and bottom margins, respectively. Figure 1 shows the default left margin of 0.50″, and the default bottom margin is 0.75″. Extra fixed offsets are added to these margins when printing EPS files as described below.

The **RESOLUTION** setting gives the target physical printing resolution. The default resolution is 600 dots per inch. This value is not directly used in the output Encapsulated PostScript data, which only contains vector graphics; but rather it is used to calculate the width of line strokes, such as for staff lines and note stems. In this case staff lines have the **LINE_width** of 4 pixels at 600 DPI **RESOLUTION**, or 0.00667″ (0.48pt). An extra 0.0007206pt is added to the line width in SCORE EPS output for some reason, which has no predictable effect on a conversion of the graphical notation to a bitmap. Due to stroke-adjust quantization effects described in Section 9 starting on page 31, specifying a 4-pixel wide line will actually generate a 5-pixel wide staff line.

The edges of all graphical objects (except for beams which have a separate stroke-width control in the SCORE preferences file) will be outlined with a line of this thickness (which will cause each objects' size to be increased by 0.24pt on all edges from their fill outline).

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[2] PostScript printing units are in points, so most of the physical length units in this document are given in points as well as inches. One inch is equivalent to 72 PostScript points (1″=72pt).

In other words, staff lines have a width of 0.48pt, with 0.24pt extending above the unstroked line/edge, and 0.24pt extending below the unstroked line/edge. Staff lines do not have endcaps, so the left and right edges of staff lines do not have an extra horizontal adjustment of 0.24pt. Note that the P5 value of staff lines may affect the staffline thicknesses: if P5<0.65, one pixel will be subtracted from a staff line's width (making the staff lines 4 pixels wide when using 600-DPI rendering).

The **PAPER** and **ROTATE** settings control paper selection and orientation but are not directly relevant to staff positioning. Any paper type or rotation (`No` = portrait/`Yes` = landscape) will still use the bottom left corner of the page as the origin, so all music printed on any paper type will be in reference to this origin. In other words, paper size and orientation information is not really needed when printing to EPS files in SCORE. However, if the EPS file is converted to a TIFF image, the height of the page needs to be known since the origin for bitmaps is traditionally the top left corner rather than the bottom left corner for PostScript files.

3 Default page positions of staff lines

Once the printing variables **OFFSETS** and **SIZE** are specified, the actual physical positions of staves on a page can be calculated. First note that the physical margin from the left edge of the page to the left-hand side of the staff lines is equal to the first **OFFSETS** number (0.5″ or 36pt default), plus an additional 0.025″ (1.8pt) shift to the right. Therefore when the left offset is 0.5″ (36pt), the actual left margin to P3=0.0 for staves will be 0.525″ (37.8pt). The extra shift of 1.8 points may be done within SCORE in order to provide extra space for system brackets (which actually ends up being 31.464pt–0.2403603pt = 31.224pt or 0.433667″ from left page edge), or braces (30.168pt–0.24pt = 29.928pt or 0.415667" from the left page edge). Since the full length of staff lines is 7.5″ (540pt), the right margin (distance from the right edge of the page to the right side of the staff lines at P6=200.0) will be 8.5″–7.5″–0.5″–0.025″= 0.475″ (34.2pt).

The bottom margin is the second number in the **OFFSETS** print setting, which is 0.75″ by default. To this margin setting, an extra 4.5pt (0.0625″) offset is also added. Therefore the default bottom margin is 0.8125″ (58.5pt) from the bottom edge of the page to the center of the bottom line of the first staff when it is in its default position (subtract 0.2403603pt if the default stroke width is applied to the staff line).

Once the bottom margin is specified, the default vertical positions of staves on the page can be calculated. Staff 1 is the bottom staff on the page. The center of the bottom line on this staff is placed BM+Bx above the bottom edge of the paper, where BM is the "Bottom Margin" as specified in the **OFFSETS** print setting, and Bx is a fixed length of 4.5pt (0.0625″). Each successive staff number is placed by default 56.7pt (0.7875″) higher than the previous staff number. This distance is from the center of the bottom line of one staff to the center of the bottom line on the next staff. In other words, the equation that calculates the vertical physical position in inches or points for a staff (referenced to the center of the bottom line on a staff) in its default position is:

$$Vpos = BM + Bx + (P2 - 1) * Vx * S$$

where Vx is the constant default vertical spacing between staves (56.7pt, 0.7875″), P2 is the staff number (P2=1 for the bottom staff, P2=2 for the next higher staff, etc.), and S is the SIZE print parameter that scales the page. Note that the scaling factor, S, does not affect the bottom margin or extra bottom offset values. Here are the vertical positions of staves from the bottom edge of the page, using the default bottom margin of 0.75″ and default page scaling size of 1.0:

Staff 1: BM + Bx + (1 – 1) * Vx * 1= BM + Bx = 58.5pt
Staff 2: BM + Bx + (2 – 1) * Vx = 58.5pt + 56.7pt = 115.2pt
Staff 3: BM + Bx + 2 * Vx = 171.9pt
Staff 4: BM + Bx + 3 * Vx = 228.6pt
Staff 5: BM + Bx + 4 * Vx = 285.3pt

Staff 6:	BM + Bx + 5 * Vx	= 342.0pt
Staff 7:	BM + Bx + 6 * Vx	= 398.7pt
Staff 8:	BM + Bx + 7 * Vx	= 455.4pt
Staff 9:	BM + Bx + 8 * Vx	= 512.1pt
Staff 10:	BM + Bx + 9 * Vx	= 568.8pt
Staff 11:	BM + Bx + 10 * Vx	= 625.5pt
Staff 12:	BM + Bx + 11 * Vx	= 682.2pt

These positions were verified in Adobe Illustrator where the positions from the bottom lines of staves to the bottom edge of the page were measured to exactly match the above calculated values (see Appendix I). The distance between staff lines at the default size is 6.3pt (0.0875″), so the height of the default-sized staff from the center of the bottom line to the center of the top line is 4 * 6.3pt = 25.2pt (0.35″), plus an additional 0.480726pt for the distance from the bottom edge of the bottom staff line to the top edge of the top staff line. Thus the center of the top line on staff 12 is 682.2pt+25.2pt = 707.4pt above the bottom edge of the paper. If the paper is letter-sized (8.5″x11″), then the page height is 792pt, which means that the distance between the top edge of the page and the center of the top line of staff 12 is 792pt–707.4pt = 84.6pt. As an aside, note that SCORE quantizes the vertical space between adjacent staff lines to 175 dots at 4000 DPI in EPS output.

The horizontal position of the default left staff position is simpler to calculate:

Hpos = LM + Lx

where LM is the "Left Margin" as specified in the **OFFSETS** print setting, and Lx is a fixed left margin offset to the right of 1.8pt (0.025″). The length of the staff at the default size is 7.5″ (540pt), so the horizontal position of the right side of the full-length staff will be 7.5″ greater than Hpos.

4 Staff positioning parameters

Five parameters of staff objects (P1=8) control the position of standard 5-line staves on the page (unless P10 is non-zero).

- **P2** is the staff number that controls the default vertical position of the staff on the page as described above.
- **P3** is the horizontal position of the left side of the staff in terms of horizontal SCORE units.
- **P4** is the vertical position of the staff in terms of vertical SCORE units (vertical scale steps, or ½ of the distance between staff lines).
- **P5** is the scaling of the staff, which adjusts the vertical height of the staff but does not affect the horizontal length of the staff (which is controlled by P3/P6).
- **P6** is the horizontal position of the right side of the staff in terms of horizontal SCORE units. If P6=0, then this means that P6 is the default value of 200 for the right margin.

SCORE horizontal units range from 0.0 for the left side of the default staff positions to 200.0 at the right side of the default staff position. These values are not physical, but rather are used to describe ratios of the final physical length. For example, to indent the first system, P3 may be set to 15.0, this means that there is an additional indent from the left margin equivalent to 15/2% = 7.5% of the length for the default staff. At the default length at the default size, this would be 7.5″ * 0.075 = 0.5625″ (40.5pt) to the right of the left margin (including the left margin extra fixed offset of 0.025″). P6 controls the position of the right side of the staff. So if P6 = 200.0 – 15.0 = 185.0, then the right side of the default staff length would be an extra 0.5625″ to the left of the right margin of the paper.

P4 is the vertical adjustment from the default position for a staff. The physical units of P4 are dependent on two scalings: (1) the **SIZE** print setting and (2) the P5 value which is the vertical scaling of the staff. In other words, if P4=2 and P5=1 and the **SIZE** print setting is 1.0, then the staff will be raised on the page by 6.3pt. If P4=4 and P5=0.5 and **SIZE** is 1.0, then the staff would also be raised on the page by 6.3pt.

As an aside, note that at the default vertical scaling P5=1, the units of P4 are 7/6 the size of the horizontal units of P3. Or in other words, if P5=6/7=85.7142857142857…, the vertical (P4) and horizontal (P3) units have the same physical length. If you want a vertical line to have the same physical length as a horizontal line, then the equation would be: ΔP4 = ΔP3 * 6/7 / P5. For example, a 1-inch line has a horizontal length of 1/7.5*200 =26.667 P3 units. This would be 22.857 P4 units when the vertical scaling P5 is 1.0.

Considering these 5 staff parameters, the full equation for calculating the physical position of the left edge of a staff, referenced from the center of the bottom line of the staff to the bottom edge of the page is:

$$Vpos = BM + Bx + [\,(P2-1) * Vx + P4 * P5 * Step\,] * S$$

Where BM = bottom margin from **OFFSETS** print setting, Bx is a fixed distance of 4.5pt (0.0625″), P2 is the staff number, Vx is the default distance between the bottom line of successive staff lines (56.7pt, 0.7875″), P4 is the vertical offset in SCORE vertical units, P5 is the staff scaling, Step is the default distance between staff lines divided by 2 (3.15pt, 0. 04375″), and S is the **SIZE** print setting. Note that if P5=0, then use a value of 1 for P5.

The vertical position of the top of a particular staff is given by the following equation, referenced to the center of the top of a 5-line staff:

Vtop = Vpos + Step * 8 * P5 * S

Vpos and Vtop are both in reference to the center of staff lines. To calculate the vertical position of the optical boundary of the bottom and top of the staff, subtract ½ of the stroke width for the staff lines which is 0.4807206pt/2 = 0.2403603pt for the default thickness of 4 pixels at 600 DPI (plus 0.00072pt):

Optical staff bottom edge = Vpos – Pixels/DPI/2 inches – ε/2
Optical staff top edge = Vtop + Pixels/DPI/2 inches + ε/2

where DPI is the dots per inch RESOLUTION setting in the print menu, and Pixels is the LINE_width print setting. The constant ε = 0.0007206pt (about 0.00001″) is an extra width SCORE EPS output adds to the line thickness (perhaps as a `float` round-off error).

The horizontal position of the left side of a staff line is given by the fully generalized equation:

Hpos = LM + Lx + S * (Len * P3/200)

Where Len is the default length of staff lines, which is 7.5″ (540pt). The fully generalized equation that calculates the distance from the left edge of the paper to the right side of a staff is similarly:

Hright = LM + Lx + S * (Len * P6/200)

If P6=0.0, then use the default value of 200.0 for the full-length width. Hpos and Hright do not need extra adjustment related to the line stroke-width, although the addition of barlines at a staff edge may increase the apparent width of the staff due to stroking effects on the barlines.

5 Basic simulation of SCORE staff printing

Based on the description of the physical placement of staves on the page in SCORE in the previous sections, the following PERL script will accept any SCORE PMX data file (in ASCII format) and output a US-Letter sized page with identical placement of staves on the page when compared to the SCORE output (excluding quantization errors addressed in later sections).

scrstaff.pl

```
#!/usr/bin/perl
use strict;

# Print variables:
my $S          = 1.0;              # global music scaling
my $LM         = 0.50 * 72.0;      # left margin
my $BM         = 0.75 * 72.0;      # right margin
my $DPI        = 600;              # target print resolution
my $LINE_width = 4;                # pixel width of line strokes
my $Stroke     = (1.0 * $LINE_width) / $DPI * 72.0;  # stroke width
$Stroke += 0.0007206;  # match behavior in SCORE

# Constants:
my $Lx         = 0.025   * 72.0;   # left margin buffer
my $Bx         = 0.0625  * 72.0;   # bottom margin buffer
my $Len        = 7.5     * 72.0;   # default full length of staff
my $Step       = 0.04375 * 72.0;   # vertical diatonic step size
my $Vx         = 0.7875  * 72.0;   # default spacing of successive staves

print "%!PS-Adobe-2.0 EPSF-1.2\n"; # print PostScript marker
print "$Stroke setlinewidth\n";    # set line stroke width
print "gsave\n";
while (my $line = <>) {
   next if $line !~ /^8/;
   printStaffObject($line);
}
print "grestore\n";
exit(0);

##############################
##
## printStaffObject -- Place a staff on the page based on its SCORE
##      PMX data.
##

sub printStaffObject {
   my ($line) = @_;
   chomp $line;
   my @data   = split(/\s+/, $line);
```

```
   my ($P1, $P2, $P3, $P4, $P5, $P6) = @data;
   $P1 *= 1; $P2 *= 1; $P3 *= 1; $P4 *= 1; $P5 *= 1; $P6 *= 1;
   $P5 =   1.0 if $P5 == 0.0;
   $P6 = 200.0 if $P6 == 0.0;
   my $hpos  = $LM + $Lx + $S * ($Len * $P3 / 2.0);
   my $width = $S  * ($Len*($P6-$P3)/200.0);
   my $vpos  = $BM + $Bx + $S*(($P2-1)*$Vx+$P4*$P5*$Step);
   my $linespacing = $Step * 2 * $S * $P5;

   print "   gsave\n";
   print "      %SCORE%", join(" ", @data), "\n";
   print "      $hpos $vpos translate\n";
   printStaffLines(5, $linespacing, $width);
   print "   grestore\n";
}

##############################
##
## printStaffLines -- print the specified number of lines with the given
##     vertical spacing between lines.  Starting point before calling
##     this function is (0, 0).
##

sub printStaffLines {
   my ($count, $vspace, $width) = @_;
   my $hleft  = 0.0;
   my $hright = $hleft + $width;
   my $vpos = 0.0;
   for (my $i=0; $i<$count; $i++) {
      $vpos = $vspace * $i;
      print "      $hleft $vpos moveto\n";
      print "      $hright $vpos lineto\n";
   }
   print "      stroke\n";
}
```

Figure 2 shows example SCORE PMX data for staves in their default positions on a page that can be input into the *scrstaff* program above to generate the EPS file output found further below. A visual representation of the data after being converted to EPS by SCORE is displayed in Appendix I (page 34).

```
8  1  0
8  2  0
8  3  0
8  4  0
8  5  0
8  6  0
8  7  0
8  8  0
8  9  0
8 10  0
8 11  0
8 12  0
t 12 56.360   20. 1 1.327 0 0 0 0 0
_00Default staff positions and sizes
t 12 40.268   15. 1 1.000 0 0 0 0 0
_00Page size 8.5"x11", left margin 0.5", bottom margin 0.75"
```

Figure 2: SCORE PMX data used to generate the page in Appendix I.

Lines starting with "8" are staff objects. Lines starting with "t" are two-line text objects (there "t" translates to P1=16 in the SCORE editor or binary PMX data), with the text for the object placed on the second line. Font "_00" at the start of the text string means Times-Roman. Here is the output of the *scrstaff* program given the PMX data found in Figure 2:

```
%!PS-Adobe-2.0 EPSF-1.2
0.4807206 setlinewidth
gsave
   gsave
      %SCORE%8 1 0
      37.8 58.5 translate
      0 0 moveto
      540 0 lineto
      0 6.3 moveto
      540 6.3 lineto
      0 12.6 moveto
      540 12.6 lineto
      0 18.9 moveto
      540 18.9 lineto
      0 25.2 moveto
      540 25.2 lineto
      stroke
   grestore
   gsave
      %SCORE%8 2 0
      37.8 115.2 translate
      0 0 moveto
      540 0 lineto
      0 6.3 moveto
      540 6.3 lineto
      0 12.6 moveto
      540 12.6 lineto
      0 18.9 moveto
      540 18.9 lineto
      0 25.2 moveto
      540 25.2 lineto
      stroke
   grestore
   gsave
      %SCORE%8 3 0
      37.8 171.9 translate
      0 0 moveto
      540 0 lineto
      0 6.3 moveto
      540 6.3 lineto
      0 12.6 moveto
      540 12.6 lineto
      0 18.9 moveto
      540 18.9 lineto
      0 25.2 moveto
      540 25.2 lineto
      stroke
   grestore
   gsave
      %SCORE%8 4 0
      37.8 228.6 translate
      0 0 moveto
      540 0 lineto
      0 6.3 moveto
      540 6.3 lineto
      0 12.6 moveto
      540 12.6 lineto
      0 18.9 moveto
      540 18.9 lineto
      0 25.2 moveto
      540 25.2 lineto
      stroke
   grestore
   gsave
      %SCORE%8 5 0
      37.8 285.3 translate
      0 0 moveto
      540 0 lineto
      0 6.3 moveto
      540 6.3 lineto
      0 12.6 moveto
      540 12.6 lineto
      0 18.9 moveto
      540 18.9 lineto
      0 25.2 moveto
      540 25.2 lineto
      stroke
   grestore
   gsave
      %SCORE%8 6 0
      37.8 342 translate
      0 0 moveto
      540 0 lineto
      0 6.3 moveto
      540 6.3 lineto
      0 12.6 moveto
      540 12.6 lineto
      0 18.9 moveto
      540 18.9 lineto
      0 25.2 moveto
      540 25.2 lineto
      stroke
   grestore
   gsave
      %SCORE%8 7 0
      37.8 398.7 translate
      0 0 moveto
      540 0 lineto
      0 6.3 moveto
      540 6.3 lineto
      0 12.6 moveto
      540 12.6 lineto
      0 18.9 moveto
      540 18.9 lineto
      0 25.2 moveto
      540 25.2 lineto
      stroke
   grestore
```

```
gsave
   %SCORE%8 8 0
   37.8 455.4 translate
   0 0 moveto
   540 0 lineto
   0 6.3 moveto
   540 6.3 lineto
   0 12.6 moveto
   540 12.6 lineto
   0 18.9 moveto
   540 18.9 lineto
   0 25.2 moveto
   540 25.2 lineto
   stroke
grestore
gsave
   %SCORE%8 9 0
   37.8 512.1 translate
   0 0 moveto
   540 0 lineto
   0 6.3 moveto
   540 6.3 lineto
   0 12.6 moveto
   540 12.6 lineto
   0 18.9 moveto
   540 18.9 lineto
   0 25.2 moveto
   540 25.2 lineto
   stroke
grestore
gsave
   %SCORE%8 10 0
   37.8 568.8 translate
   0 0 moveto
   540 0 lineto
   0 6.3 moveto
   540 6.3 lineto
   0 12.6 moveto
   540 12.6 lineto
   0 18.9 moveto
   540 18.9 lineto
   0 25.2 moveto
   540 25.2 lineto
   stroke
grestore
gsave
   %SCORE%8 11 0
   37.8 625.5 translate
   0 0 moveto
   540 0 lineto
   0 6.3 moveto
   540 6.3 lineto
   0 12.6 moveto
   540 12.6 lineto
   0 18.9 moveto
   540 18.9 lineto
   0 25.2 moveto
   540 25.2 lineto
   stroke
grestore
gsave
   %SCORE%8 12 0
   37.8 682.2 translate
   0 0 moveto
   540 0 lineto
   0 6.3 moveto
   540 6.3 lineto
   0 12.6 moveto
   540 12.6 lineto
   0 18.9 moveto
   540 18.9 lineto
   0 25.2 moveto
   540 25.2 lineto
   stroke
grestore
grestore
```

6 Analysis of SCORE EPS output

As a comparison to the simulated graphical output generated in the last section, the following EPS code represents a single staff at the bottom of the page. This is equivalent to the first staff drawn in the above PostScript code. The SCORE PMX data for the following EPS code is:

```
8 1 0
```

where P1=8 means a staff object, P2=1 means staff #1, and all other parameters are set to zero (which may mean use the default setting, such as P6 and P5 in the case of staff objects).

This program contains a section of code at the start of the file with function defines and aliases. For example "`/m /moveto load def`" is a function definition which creates and alias "`m`" which can be used in place of the built-in function "`moveto`". Note that there is an extra space at the start of each line. This is added in SCORE EPS output to avoid problems caused by end-of-line differences on MS-DOS/Windows and Apple systems.

```
%!PS-Adobe-2.0 EPSF-1.2
%%Creator: SCORE (tm) Ver. 4.00, Serial #      0
%%Title: SCORE.MUS
%%BoundingBox: 37 57 579 85
%%DocumentFonts: (atend)
%%EndComments
 /scoredict 200 dict def scoredict begin
 save
 /m /moveto load def /l /lineto load def
 /setstrokeadjust where
 { pop true setstrokeadjust }
 { /m { transform .25 sub round .25 add exch .25 sub round .25 add exch
 itransform  moveto } bind def
 /l { transform .25 sub round .25 add exch .25 sub round .25 add exch
 itransform  lineto } bind def } ifelse
 /tr /translate load def /aw /awidthshow load def
 /e /eofill load def /s /stroke load def /g /gsave load def /r
/grestore load def
 /f /findfont load def /sf /setfont load def
 /mkf /makefont load def /lw /setlinewidth load def
 newpath /SCORE  {
 /size  .01800 def  /wdl   26.7067 def
 size dup scale   wdl lw  1 setlinejoin
 /lmar   2100 def /bmar  27250 def
 lmar bmar tr} def
 g SCORE
 0 -24000 m
 30000 -24000 l
 0 -23650 m
```

```
 30000 -23650 l
 0 -23300 m
 30000 -23300 l
 0 -22950 m
 30000 -22950 l
 0 -22600 m
 30000 -22600 l
 s
showpage
r restore
end
%%Trailer
%%DocumentFonts:
```

The simple function definitions given in the header are:

```
/m   /moveto       load def
/l   /lineto       load def
/tr  /translate    load def
/aw  /awidthshow   load def
/e   /eofill       load def
/s   /stroke       load def
/g   /gsave        load def
/r   /grestore     load def
/f   /findfont     load def
/sf  /setfont      load def
/mkf /makefont     load def
/lw  /setlinewidth load def
```

The main non-trivial function definition is `/SCORE`, which is used to do basic setup at the start of a page:

```
/SCORE  {
     /size  .01800 def
     /wdl   26.7067 def
     size dup scale
     wdl lw
     1 setlinejoin
     /lmar   2100 def
     /bmar  27250 def
     lmar bmar tr
} def
```

First the units for the page are set so that "1" represents 0.01800pt rather than 1pt. In other words the point is divided into 55.555555… units. The reason for this scaling is that SCORE prints internally with a 4000-DPI quantization, which could be residual behavior from the plotting method that SCORE used for printing before PostScript. The scaling of 0.018 for the page makes each integer unit (pixel) equal to 1/4000″: 0.018 points/unit / (72 points/inch) = 1/4000 inch/unit, which therefore is a resolution of 4000 DPI. In any case, since 55.5555… is a repeating fraction, there will be round-off

error ≤ 0.00025″ (0. 0000034722pt) from the original layout precision in the data since all SCORE position coordinates in the EPS file are integers at 4000 DPI.

Besides adjusting the page scale by 0.018 to emulate 4000 DPI, the `/SCORE` function moves the origin up from the bottom left edge of the page to (2100, 27250). Since the printing units are equivalent 1/4000″, the origin is moved to (0.525″, 6.8125″). The horizontal value of 0.525″ matches the measured distance between the left edge of the paper and the left side of the staves when they are in their default positions. The reason for the origin's vertical position of 6.8125″ above the bottom edge of the page is unknown. It is equivalent to the bottom margin specified in the print menu (0.75″ is the default value used in this case, plus 0.0625″ fixed vertical margin offset plus 6.0″). Again, this 6″ vertical offset from the bottom margin may be a remnant of the printing process before PostScript was used. It also may be used to minimize the maximum page coordinate value from 44000 to 24000 for some reason (such as to keep coordinate values less than a signed short which is 32767) which may have been necessary for the pen-plotting method used to print graphical music notation from SCORE prior to PostScript.

The line width that is used to stroke the staff lines is set to 26.7067 units or 0.4807206pt. The expected width is 0.48pt. The significance of the extra 0.0007206pt is uncertain, but may be related to the internal quantization in SCORE EPS position calculations, since 0.0007206pt is 0.0000100083333″. Since 1/4000″ is 0.00025″, the difference of 0.0007206 is equivalent to 1/24.979184 of the length 1/4000″. Excluding the round-off error of 0.0000006pt, the difference would be exactly 1/25 of a 4000 DPI pixel. So the default width of a line stroke in SCORE EPS output is 0.48pt plus 1/25 of 1/4000″, which is 0.48072pt plus a round-off error of 0.0000006pt, making the final thickness 0.4807206pt. In practice this small addition to the line width is irrelevant due to the stroke-adjustment process described in Section 9 (starting on page 31).

When the print setting **SETSTROKE** is set to "`YES`" (see Figure 1 on page 5), the following code is inserted into SCORE EPS output to redefine the "`l`" and "`m`" drawing functions. The code will switch drawing points into the rendering coordinate system, then it does a quarter pixel shift followed by a rounding to the nearest pixel before shifting back a quarter pixel and switching back into the PostScript coordinate system.

```
/setstrokeadjust where
{ pop true setstrokeadjust }
{ /m {
        transform
        .25 sub round .25 add exch
        .25 sub round .25 add exch
        itransform  moveto
    } bind def
  /l {
        transform
        .25 sub round .25 add exch
        .25 sub round .25 add exch
        itransform  lineto
    } bind def
} ifelse
```

Such code gives a consistent pixel width to stroked lines and is used by most PostScript renderers "to improve line thickness consistency in lower resolutions."[3] Official description and motivation of the *setstrokeadjust* feature which this code is copied from can be found at Adobe's website.[4] Section 9 starting on page 31 goes into more detail about the significance of the above code snippet.

[3] http://www.creativepro.com/article/acrobat-tips-graphics-in-pdfs?page=0%2C2

[4] http://partners.adobe.com/public/developer/en/ps/sdk/5111.Stroke_Adj.pdf, "Emulation of the setstrokeadjust Operator" Technical Note #5111, 31 March 1992, Adobe Systems, San Jose, California.

7 Bitmap comparison of simulation to SCORE EPS

A useful method for analyzing the simulated staff printing generated by the *scrstaff* program listed in Section 1 is to convert the SCORE Encapsulated PostScript file into a bitmapped image, convert the simulated printing result to a bitmapped image, and then examine differences between the two images by comparing the pixels between the two images. To generate a bitmap from an EPS file, GhostScript is a good choice. GhostScript is typically installed on Linux computers by default (and accessible via the "`gs`" command-line program).

To install GhostScript on an Apple OS X computer, you should first install MacPorts.[5] Once MacPorts is installed, type this command in /Applications/Utilities/Terminal.app:

```
sudo port install ghostscript
```

After installing GhostScript, the `gs` command should be accessible. Type the following command in the terminal to see if the `gs` program can be found in the command search path list:

```
which gs
```

The following (or similar) text should then be displayed:

```
/usr/bin/gs
```

If no text is displayed, then GhostScript is not likely to be installed on the computer. If GhostScript is installed, you can convert an EPS file into a TIFF image with this terminal command:

```
gs -r600 -dNOPAUSE -dBATCH -sPAPERSIZE=letter \
      -sDEVICE=tifflzw -sOutputFile=output.tif input.eps
```

This command will convert `input.eps` into `output.tif`. The options given to `gs` are:

`-r600`	convert to 600 DPI bitmap
`-dNOPAUSE -dBATCH`	don't go into interactive mode with the gs interpreter
`-sPAPERSIZE=letter`	set the paper size to US Letter. This is required, since SCORE does not store the paper size in its output EPS file, and gs usually uses A4 as the default paper size
`-sDEVICE=tifflzw`	output content is a TIFF image using LZW compression
`-sOutputFile=output.tif`	set output filename to output.tif
`input.eps`	the input EPS file

[5] Install MacPorts from the website http://www.macports.org by downloading and installing the most recent installation package for your particular version of OS X, such as:
https://distfiles.macports.org/MacPorts/MacPorts-2.1.0-10.7-Lion.pkg
which would be the installation file for MacPorts version 2.1.0-10.7 for OS X Lion.

The following PERL script, called *maketiff*, can be used to convert EPS files into TIFF images without the need to remember all of the GhostScript options:

maketiff.pl

```
#!/usr/bin/perl

use strict;

foreach my $file (@ARGV) {
   convert($file);
}

sub convert {
   my ($file) = @_;
   my $basename = $file;
   $basename =~ s/\.[^.]*//;
   my $gsopts  = " -r600";                  # 600 dpi
   $gsopts    .= " -dNOPAUSE -dBATCH";      # non-interactive use of GhostScript
   $gsopts    .= " -sPAPERSIZE=letter";     # use 8.5" by 11" paper
   $gsopts    .= " -sDEVICE=tifflzw";       # B&W TIFF with LZW compression
   $gsopts    .= " -sOutputFile=$basename.tif";
   my $result  = `gs $gsopts $file`;
   print "gs $gsopts $file\n";
   print $result;
}
```

The `convert`, `compare` and `composite` commands, which are part of the ImageMagick package, can be used to examine differences between two image files.[6] These programs are typically pre-installed on Linux systems, and can be installed using MacPorts in OS X with the following command:

```
sudo port install ImageMagick
```

The first comparison method uses `composite` to subtract the two images from each other. Then the `convert` command is used to switch black/white.

```
composite file1.tif file2.tif -compose difference output.png
convert output.png –negate output.tif
```

The output file in the composite command cannot be a TIFF file; otherwise, the entire image is black for some reason (probably related to the input file being only black & white and not grayscale or color). So in this case the intermediate output is saved to a PNG file that is then negated and converted into the final TIFF file. An alternate method of dis-

[6] Documentation for these programs can be found on the web at:
http://www.imagemagick.org/script/convert.php,
http://www.imagemagick.org/script/compare.php,
http://www.imagemagick.org/script/composite.php

playing differences is with the `compare` command. This command highlights differences using red pixels along with unaltered pixels when they match between the two images:

```
compare file1.tif file2.tif output.png
convert output.png output.tif
```

Figure 3 shows the resulting difference image comparing the TIFF image of the SCORE PMX data found in Figure 2 which is printed directly from SCORE with the output from the *scrstaff* PERL script. All pixels (at 600 DPI resolution) are equivalent between the two images, other than the text at the top of the page, which is ignored by the *scrstaff* program.

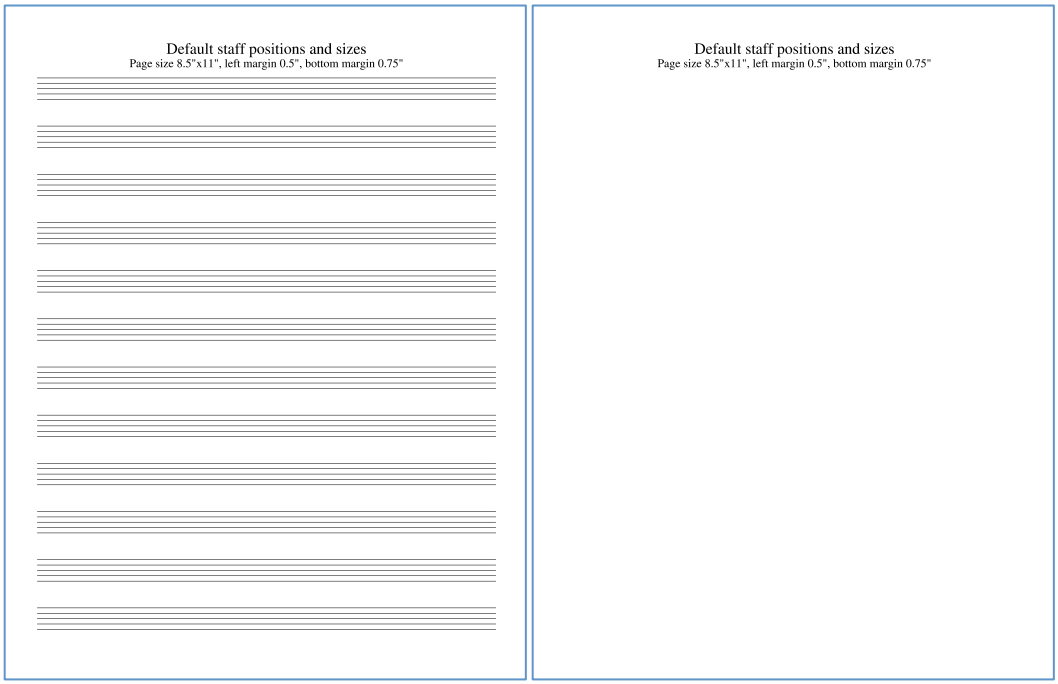


Figure 3: The left image represents the output SCORE EPS file using the PMX data from **Figure 2**. The right image shows the difference between the SCORE EPS output and the simulated EPS output found at the end of Section 1. The simulation was accurate to the pixel in placing the staff lines since there are no pixels differences showing up in the image on the right.

8 4000-DPI quantization effects

The exact 600-DPI alignment between the two comparison images in the previous section turns out to be a coincidence. A more complicated example is used for evaluation with randomly positioned staff lines which shows small differences between SCORE EPS files and the simulated EPS output from the *scrstaff* program. Figure 4 shows the input SCORE PMX data for the following test of a wider range of staff placements.

```
8  6  20   -23   3.00  178.60
8  2   0    11
8  4 120     0    .25  180.00
8  7   0     0   2.00
8  8 101.45  0    .00  102.36
8  9   0     0   3.00  100.00
8 10 100    -6   3.00
8  1   0
8  5   0     0    .00   10.00
8  6  40     0    .75
8 11  45.63  0   4.00   95.24
8 12  -3     0    .00   30.00
t 12 111.01 14 1 1.327 0 0 0 0 0
_00Random staff placement test
```

Figure 4: SCORE PMX data for a set of randomly placed staff lines.

Figure 5 shows several staff lines that differ by one pixel due to quantization effects. The differences are caused by the SCORE editor printing method that imposes a quantization of 4000 DPI when printing an EPS file. When this 4000-DPI quantization rounds in such a way that its 600 dpi rounding will be different from the pre-quantized position (about 1/6 of the time for random coordinates), there will be a one-pixel discrepancy between the two bitmap-generating methods.

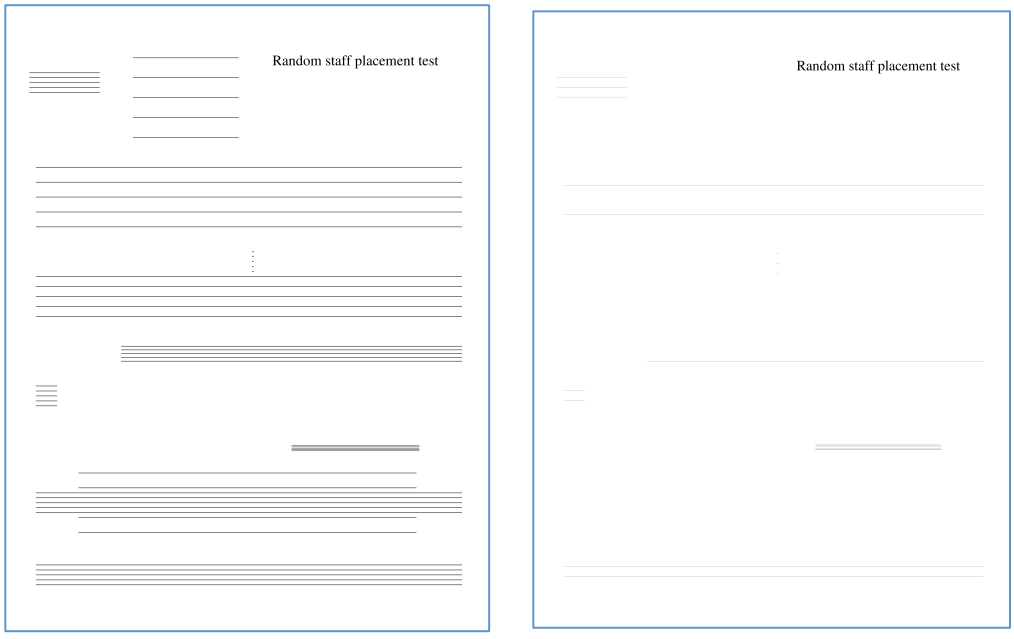


Figure 5: The left image show randomly placed staff lines created from the SCORE PMX data listed in **Figure 3**. The right image shows the difference between the SCORE EPS and simulated EPS after both are converted into 600 DPI images. Notice the occasional one-pixel difference between the two images caused by SCORE's 4000-DPI quantization.

To correct for the 4000-DPI quantization used by the SCORE editor to print EPS files, a revised version of *scrstaff* is given below. This version of the staff-printing script uses the SCORE EPS method of first switching to a 4000-DPI coordinate system where the origin is shifted to the left margin and six inches above the bottom margin, and then outputting quantized coordinates in the resulting EPS file.

scrstaffq.pl

```
#!/usr/bin/perl
#
# scrstaffq = Print staff lines from SCORE PMX data, applying 4000 DPI
#    quantization.  Use -Q option to turn off the quantization.
#
# Only one vertical position quantized incorrectly from a test set
# of 1000 staves:
#    8.000000 2.000000 134.886353 -5.738704 1.465246 195.576492
# 4th line of staff is:
#    20232 -20782 m
#    29336 -20782 l
# but should be:
#    20232 -20783 m
#    29336 -20783 l
#

use strict;
use POSIX;

use Getopt::Long;
my $noquantize = 0;
Getopt::Long::Configure("bundling");
GetOptions ( 'Q' => \$noquantize );  # -Q means turn off 4000-DPI quantization

# Command-line options:
my $quant4000 = !$noquantize;      # simulate SCORE EPS quantization at 4000 DPI

# SCORE print menu variables:
my $S          = 1.0;              # global music scaling
my $LM         = 0.50 * 72.0;      # left margin
my $BM         = 0.75 * 72.0;      # right margin
my $DPI        = 600;              # target print resolution
my $LINE_width = 4;                # pixel width of line strokes
my $Stroke     = (1.0 * $LINE_width) / $DPI * 72.0;  # stroke width

# Constants:
my $Lx         = 0.025   * 72.0;   # left margin buffer
my $Bx         = 0.0625  * 72.0;   # bottom margin buffer
my $Len        = 7.5     * 72.0;   # default full length of staff
my $Step       = 0.04375 * 72.0;   # vertical diatonic step size
my $Vx         = 0.7875  * 72.0;   # default spacing of successive staves

my $dpi72to4000  = 4000.0 / 72.0;  # conversion factor from points to 4000 DPI
my $hoffset4000 = ($LM + $Lx) * $dpi72to4000;           # should be 2100
my $voffset4000 = ($BM + $Bx + 6 * 72) * $dpi72to4000;  # should be 27250
```

```
$Stroke += 0.0007206;  # match line thickness behavior in SCORE
$Stroke *= $dpi72to4000;
my  $LW = $Stroke;     # Variables for keeping track of the stroke width which
my  $oldLW = $Stroke;  #    is needed since gsave/grestore are not used.


print "%!PS-Adobe-2.0 EPSF-1.2\n"; # print PostScript marker

# print PostScript functions:
print "/m {moveto} def\n";
print "/l {lineto} def\n";
print "/s {stroke} def\n";
print "/lw {setlinewidth} def\n";
print "/tr {translate} def\n";

print "\ngsave\n";
print 1.0/$dpi72to4000, " dup scale\n";  # coordinates from 72 DPI to 4000 DPI
print "$hoffset4000 $voffset4000 tr\n";
print "$LW lw\n";

while (my $line = <>) {
   next if $line !~ /^8/;
   printStaffObject($line);
}

print "grestore\n";
print "showpage\n";

exit(0);



##############################
##
## printStaffObject -- Place a staff on the page based on its SCORE
##      PMX data.
##

sub printStaffObject {
   my ($line) = @_;
   chomp $line;
   my @data   = split(/\s+/, $line);
   my ($P1, $P2, $P3, $P4, $P5, $P6) = @data;
   $P1 *= 1; $P2 *= 1; $P3 *= 1; $P4 *= 1; $P5 *= 1; $P6 *= 1;
   $P5 =   1.0 if $P5 == 0.0;
   $P6 = 200.0 if $P6 == 0.0;
   my $width  = $S  * ($Len*($P6-$P3)/200.0);
   my $hlpos  = $LM + $Lx + $S * ($Len*$P3/200.0);
   my $vpos   = $BM + $Bx + $S*(($P2-1)*$Vx+$P4*$P5*$Step);
   my $lspace = $Step * 2 * $P5 * $S;  # spacing between staff lines

   # scale to 4000 DPI coordinates (from 72 DPI coordinates):
   $hlpos  = $hlpos  * $dpi72to4000;
   $vpos   = $vpos   * $dpi72to4000;
   $width  = $width  * $dpi72to4000;
   $lspace = $lspace * $dpi72to4000;
```

```
   # print the original SCORE PMX data for the staff:
   print "%SCORE%", join(" ", @data), "\n";

   # if the stroke width has changed, print it.  This code is hard-coded
   # and shoudl be geralize.  But 20.03 is equal to 3 pixels at 600 dpi
   # (one less than default staffline width), plus a small extra amount.
   $LW = $Stroke;
   $LW = 20.03 if $P5 < 0.65;
   if ($LW != $oldLW) {
      printf("    %.4lf lw\n", $LW);
      $oldLW = $LW;
   }

   # quantize new origin (6" above bottom right margin origin)
   my $hoffset4000q = int($hoffset4000);
   my $voffset4000q = int($voffset4000);

   # print the staff on the page according to the PMX parameters:
   printStaffLines(5, $hlpos-$hoffset4000q, $width, $vpos-$voffset4000q, $P5);
}



##############################
##
## printStaffLines -- print the specified number of lines with the given
##     vertical spacing between lines.
##

sub printStaffLines {
   my ($count, $hlpos, $width, $vbottom, $P5) = @_;
   my $hshift = 0.00075;   # hack value to fix 22 /1000 quantizations
   #$hshift = 0.0;   # hack value to fix 22 /1000 quantizations

   # variables for quantized versions of values:
   my $hlposq   = $hlpos;
   my $vbottomq = $vbottom;
   my $widthq   = $width;

   $hlposq -= 0.001 if $hlposq < 0;
   $hlposq += 0.001 if $hlposq > 0;

   if ($quant4000) {
      $hlposq    = int($hlposq);
      $widthq    = int($widthq);
      $vbottomq  = int($vbottomq);
   }
   my ($vpos, $vposq);
   my $vorigin = $vbottom;

   # The bottom staff line of the staff is at vertcial unit "3" in SCORE.
   # Shift the origin down 3 steps from the bottom line of the staff.
   # the diatonic step is 175 units at 4000 DPI (3.15pt)
   my $diatonicstep = 175 * $P5;
   $vorigin = $vorigin - 3.0 * $diatonicstep;

   print "% Diatonic step: $diatonicstep\n";
```

```
   # print staff lines at diatonic steps 3, 5, 7, 9, 11:
   for (my $i=3; $i<=11; $i+=2) {
      $vpos = $vorigin + $i * $diatonicstep;
      $vposq = $vpos;

      # suppress quantization problems near integers
      $vposq -= 0.0001 if $vposq < 0;
      $vposq += 0.0001 if $vposq > 0;

      $vposq = int($vposq) if $quant4000;
      my $hrposq = $width + $hlpos;

      # suppress quantization problems near integers
      $hrposq -= 0.0001 if $hrposq < 0;
      $hrposq += 0.0001 if $hrposq > 0;

      $hrposq = int($hrposq + $hshift) if $quant4000;

      if (!$quant4000) {
         # avoid small numbers such as -1e8 when not quantizing:
         $hlposq = 0 if $hlposq =~ /e/i;
         $hrposq = 0 if $hrposq =~ /e/i;
         $vposq  = 0 if $vposq  =~ /e/i;
      }

      print " $hlposq $vposq m\n";
      print " $hrposq $vposq l\n";
   }
   print " s\n";
}
```

Figure 6 shows a 600-DPI difference analysis when printing the PMX data from SCORE and from *scrstaffq*. In this case there are now no pixel differences between the two output methods, and the 4000-DPI quantization effect seen in Figure 5 is now removed.

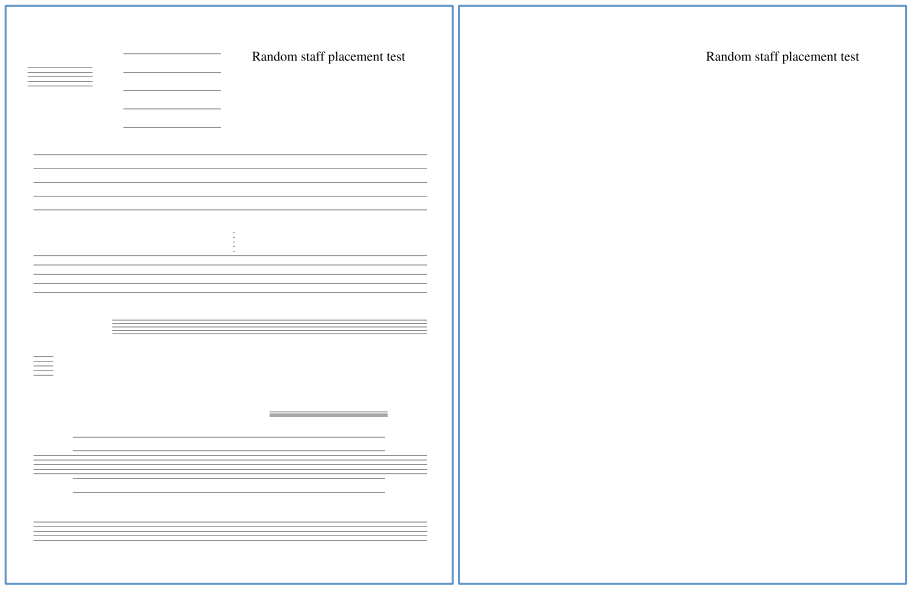


Figure 6: EPS output for the PMX data from **Figure 4**. Image on the right shows the difference between the quantized simulated output compared to the SCORE EPS output. Quantization error pixels from **Figure 5** are no longer present.

Using a more extensive random test described in Section 8.1, only one vertical position on the fourth staff line of the following PMX data is off by one 4000-DPI pixel:

```
8.000000 2.000000 134.886353 -5.738704 1.465246 195.576492
```

The vertical position of the fourth line of the staff is at -20782 in the 4000-DPI coordinate system, when the output from SCORE is at -20783. This is out of a test set of 1000 staves, or 5000 staff lines (so a measured error rate of 0.02%).

An additional complication added to the quantized version of the *scrstaffq* program is that SCORE will shrink the stroke width for staves when P5 is less than 0.65. For example when P5=1, the line thickness is 26.7067 SCORE printing units (0.4807206pt, or 0.006676675″). When P5=0.25, the thickness is 20.03 SCORE printing units (0.36054pt, or (0.0050075″). In other words, when P5 is less than 0.65, the pixel width of staff lines will be decreased by 1 pixel. For example a 0.4807206pt stroke width is 4.006005 pixels at 600 DPI, while 0.36054pt is 3.0045 pixels at 600 DPI.

8.1 Detailed random quantized staff positioning test

To exhaustively verify the quantization boundaries, the following PERL script was used to generate truly (quasi-)random staff positions. This program generates random values for P2–P6 of staff line objects. Figure 7 shows sample output from *makerandomstaff*: the text on the left lists 26 of the random staff objects, and the image on the right of the figure shows the graphic result of placing 1000 randomly generated staves on a page.

makerandomstaff.pl

```
#!/usr/bin/perl
my $count = 1000;
for ($i=0; $i<$count; $i++) {
   my $P1 = 8;                # P1=8 means staff object
   my $P2 = int(rand(12))+1; # staff number
   my $P3 = rand(200);        # left horizontal position
   my $P4 = rand(20) - 10;    # vertical offset
   my $P5 = rand(3);          # vertical scale
   my $P6 = rand(200);        # right horizontal position
   if ($p6 < $p3) {           # Put $P3 and $P6 is correct order
      my $temp = $p6;
      $p6 = $p3;
      $p3 = $ptemp;
   }
   printf("%f %f %f %f %f %f\n", $P1, $P2, $P3, $P4, $P5, $P6);
}
```

```
8 11 6.198888 9.573973 0.283635 168.128405
8 11 2.873254 -4.797876 2.927321 70.601575
8 7 87.639369 7.994754 0.598376 165.502491
8 7 41.646249 2.260639 0.923335 81.354952
8 12 0.694142 8.659682 1.671497 9.091288
8 7 141.401669 3.957960 1.272665 156.293134
8 6 56.481524 4.920927 0.341730 167.857785
8 10 72.348165 0.396136 1.237993 160.695259
8 6 33.471906 2.824829 2.398684 35.839999
8 1 8.250568 7.964336 0.584617 174.530481
8 12 32.757540 9.446832 2.429939 87.284526
8 10 162.437601 -6.53652 2.742277 170.27050
8 8 27.373900 -3.664126 1.156347 36.968902
8 9 96.360833 2.974862 2.310525 152.645578
8 9 108.015245 -4.306424 2.667651 113.96283
8 3 55.261755 -6.727791 0.970704 190.964604
8 1 52.988382 6.902256 1.430236 97.383340
8 2 2.663138 2.782467 0.111959 147.923603
8 4 139.913069 -3.690463 0.956186 143.73427
8 8 37.481259 -9.526205 0.102742 108.354876
8 7 40.561432 2.533573 1.711105 54.101457
8 4 36.023047 -7.778810 0.266028 152.194445
8 8 122.386297 8.136932 2.105072 176.946497
8 6 139.798412 -8.796644 0.437483 182.64005
8 1 49.466780 -8.467895 2.451192 57.357401
8 10 161.137762 7.532659 2.825202 165.72935
...
```

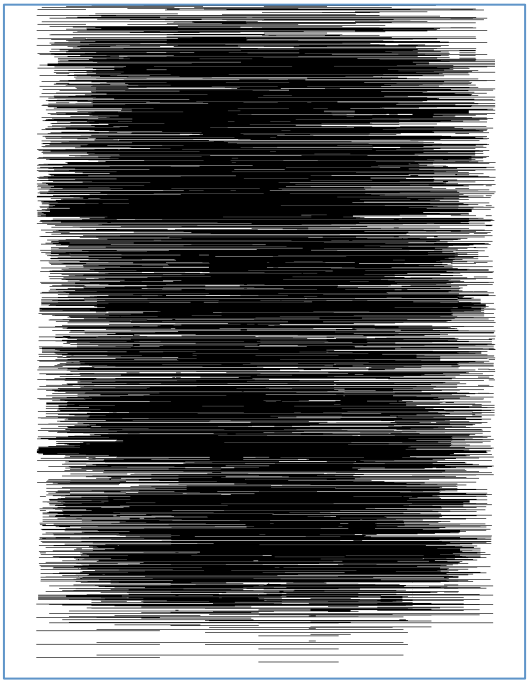


Figure 7: Sample output from *makerandomstaff* program. The page image on the right shows 1000 randomly placed staves on the page at the same time. **Appendix II** starting on page 52 contains the full listing of the 1000 staves.

For careful comparisons between SCORE EPS and simulated EPS files, it is necessary to quantize the above staff data to 32-bit floating-point numbers. SCORE processes all data numbers in this format, so the input to both printing programs should be quantize to 32-bit floats first in order to avoid trivial differences due to quantizing 64-bit floating-point numbers into 32-bit floats. Here is a C program that will quantize the example PMX data (but cannot handle SCORE text objects):

floatize.c

```
#include <stdio.h>
#include <string.h>
#include <stdlib.h>

void printFloatLine(char* buffer) {
   float value;
   char* ptr;
   int count = 0;
   ptr = strtok(buffer, " \n\t");
   while (ptr != NULL) {
      if (!sscanf(ptr, "%f", &value)) {
         printf("ERROR\n");
         exit(1);
      }
      if (count++ > 0) {
         printf(" ");
      }
      printf("%f", value);
      ptr = strtok(NULL, " \n\t");
   }
```

```
    printf("\n");
}

int main(int argc, char** argv) {
    if (argc < 2) {
        return 1;
    }
    FILE *input;
    input = fopen(argv[1], "r");
    char buffer[1024] = {0};
    while (fgets(buffer, 1024, input) != NULL) {
        printFloatLine(buffer);
    }

    fclose(input);
}
```

Below is sample input and output from *floatize*. Note that the first line of the input data ends in "5" while the float-quantized output's first line ends in "3".

```
8 11 6.198888 9.573973 0.283635 168.128405
8 11 2.873254 -4.797876 2.927321 70.601575
8 7 87.639369 7.994754 0.598376 165.502491
8 7 41.646249 2.260639 0.923335 81.354952
8 12 0.694142 8.659682 1.671497 9.091288
8 7 141.401669 3.957960 1.272665 156.293134
8 6 56.481524 4.920927 0.341730 167.857785
8 10 72.348165 0.396136 1.237993 160.695259
8 6 33.471906 2.824829 2.398684 35.839999
8 1 8.250568 7.964336 0.584617 174.530481
8 12 32.757540 9.446832 2.429939 87.284526
8 10 162.437601 -6.536518 2.742277 170.270498
8 8 27.373900 -3.664126 1.156347 36.968902
8 9 96.360833 2.974862 2.310525 152.645578
8 9 108.015245 -4.306424 2.667651 113.962831
8 3 55.261755 -6.727791 0.970704 190.964604
8 1 52.988382 6.902256 1.430236 97.383340
8 2 2.663138 2.782467 0.111959 147.923603
```

```
8.0 11.0 6.198888 9.573973 0.283635 168.128403
8.0 11.0 2.873254 -4.797876 2.927321 70.601578
8.0 7.0 87.639366 7.994754 0.598376 165.502487
8.0 7.0 41.646248 2.260639 0.923335 81.354950
8.0 12.0 0.694142 8.659682 1.671497 9.091288
8.0 7.0 141.401672 3.957960 1.272665 156.293137
8.0 6.0 56.481525 4.920927 0.341730 167.857788
8.0 10.0 72.348167 0.396136 1.237993 160.695251
8.0 6.0 33.471905 2.824829 2.398684 35.840000
8.0 1.0 8.250568 7.964336 0.584617 174.530487
8.0 12.0 32.757542 9.446832 2.429939 87.284523
8.0 10.0 162.437607 -6.536518 2.742277 170.270493
8.0 8.0 27.373899 -3.664126 1.156347 36.968903
8.0 9.0 96.360832 2.974862 2.310525 152.645584
8.0 9.0 108.015244 -4.306424 2.667651 113.962830
8.0 3.0 55.261757 -6.727791 0.970704 190.964600
8.0 1.0 52.988380 6.902256 1.430236 97.383339
8.0 2.0 2.663138 2.782467 0.111959 147.923599
```

To compare the finale EPS output from both SCORE and *scrstaffq*, the following PERL script was used:

epscompare.pl

```
#!/usr/bin/perl
use strict;

my $epsfile1  = $ARGV[0];
my $epsfile2  = $ARGV[1];
my @epshpos1  = getEpsCoordinates($epsfile1);
my @epshpos2  = getEpsCoordinates($epsfile2);
my $size1     = @epshpos1;
my $size2     = @epshpos2;
my @coord1;
my @coord2;
```

```
my @diff;

die "Coordinate count mismatch: $size1 $size2\n" if $size1 != $size2;

for (my $i=0; $i<$size1; $i++) {
   @coord1  = split(/\s+/, $epshpos1[$i]);
   @coord2  = split(/\s+/, $epshpos2[$i]);
   $diff[0] = $coord1[0] - $coord2[0];         # horizontal difference
   $diff[1] = $coord1[1] - $coord2[1];         # vertical difference
   if (abs($diff[0]) + abs($diff[1]) != 0.0) { # print only if different
      my $line = int(($i % 10) / 2.0)+1;
      my $staff = int($i / 10);
      my $bin = $i % 2;
      print "$staff: $line-$bin: ";
      print "($diff[0], $diff[1])";
      print " =\t($coord1[0], $coord1[1])$coord1[2] -\t";
      print "($coord2[0], $coord2[1])$coord2[2]\n";
   }
}

exit(0);


##############################
##
## getEpsCoordinates -- extract all moveto and lineto coordinates from a
##    SCORE EPS file.
##

sub getEpsCoordinates {
   my ($file) = @_;
   my @output;
   open (FILE, $file) or die "Cannot read $file";
   while (my $line = <FILE>) {
      chomp $line;
      if ($line =~ /^\s*([-\d\.]+)\s+([-\d\.]+)\s+m\s*$/) {
         $output[@output] = "$1\t$2\tm";
      } elsif ($line =~ /^\s*([-\d\.]+)\s+([-\d\.]+)\s+l\s*$/) {
         $output[@output] = "$1\t$2\tl";
      }
   }
   close FILE;
   return @output;
}
```

The *epscompare* script reports two quantization problems for the set of 1000 random staves (staff #592, vertical position of 4th staff line).

```
592: 4-0: (0, 1) =      (20232, -20782)m -      (20232, -20783)m
592: 4-1: (0, 1) =      (29336, -20782)l -      (29336, -20783)l
```

This quantization error could not be compensated for without causing more quantization errors on other staves. It is most likely caused by a difference in the order of quantizations for the vertical spacing between SCORE and *scrstaffq*, or a peculiarity within the SCORE editor's code.

9 Setstrokeadjust quantization effects

Section 0 covers the 4000-DPI internal quantization of SCORE EPS coordinates caused by scaling the coordinate system by 0.018 (1/4000) and then rounding coordinates of all points to integers (by truncating the fractional values rather than true rounding). An important secondary quantization effect takes place when the **STROKEADJUST** setting in the SCORE print menu is set to "`Yes`". By default this stroke-adjust setting is turned on, which causes the following PostScript code to be inserted into the EPS output data:

```
/setstrokeadjust where
{ pop true setstrokeadjust }
{ /m {
        transform
        .25 sub round .25 add exch
        .25 sub round .25 add exch
        itransform  moveto
     } bind def
  /l {
        transform
        .25 sub round .25 add exch
        .25 sub round .25 add exch
        itransform  lineto
     } bind def
} ifelse
```

This code translates into English as: "if the printing device knows about stroke adjustment, then use its built-in adjustment feature; otherwise, emulate the basic functionality of *setstrokeadjust* by quantizing to quarter-pixel boundary offsets in the rendering device's resolution".

When emulating *setstrokeadjust* functionality, this code imposes a quantization spacing for all coordinate points used by the **`m`** and **`l`** functions, including staff lines. The quantization space is that of the rendering device. For example if the device is a 300 DPI printer, the stroke adjustment will take place at that resolution, and all vector points used on the page will be quantized to quarter-pixel offsets at 300 DPI. Note that the rendering resolution is not inherently known when the vector-graphics are generated, only when the actual conversion to a quantized space is realized. The `transform` PostScript function temporarily moves the coordinate space into the absolute (continuous) positions of the rendering device where the stroke-adjust quantization takes place. The `itransform` function reverses the process, taking the coordinate space back to the original one (the user-coordinate space as Adobe calls it). In the renderer's coordinate space, the coordinate values are shifted ¼ of a pixel down, then rounded to the nearest pixel, then back by shifting up ¼ of a pixel:

x y moveto ➔ [round(device(x, dpi)-0.25) + 0.25] [round(device(y,dpi)-0.25)+0.25] moveto

There are two purposes for this code: (1) to allow all lines with the same thickness in continuous space to have also uniform thicknesses in a quantized space, and (2) to allow for both even- an odd-pixel line quantization widths. If this stroke-adjustment code is not used, any line placed at a pixel boundary in the rendering device must have a width that

is an even number of pixels, while lines placed at ½ pixels must have a width that is an odd number of pixels. This will cause lines that have equal width in continuous space to have unequal widths in a quantized space. Quantizing coordinates to the ¼ pixel positions allows for pixelated lines to have the full range of even and odd widths (Figure 8) as well as guarantees that the widths of horizontal and vertical lines remain equal after quantization. Alternatively ¾ pixel positions could also be used (see Figure 9). Here is the Adobe explanation for setstrokeadjust:

> "Why adjust to one quarter? Placing the path off center within the pixel makes it possible for the device space line width to grow one pixel at a time as the specified line width increases. Placing the path along the pixel boundary forces all line widths to use an even number of pixels and to grow two pixels at a time. Centering the path within the pixel forces all line widths to use an odd number of pixels and also to grow two pixels at a time."[7]

Figure 8 demonstrates the different line-width effects when quantizing lines at pixel boundaries as well as centered in the middle of pixels. In both cases the quantized line width can only increment by 2 pixels at a time. The quarter-pixel alignment of lines allows for 1-pixel increments in line widths, thus minimizing quantization errors.

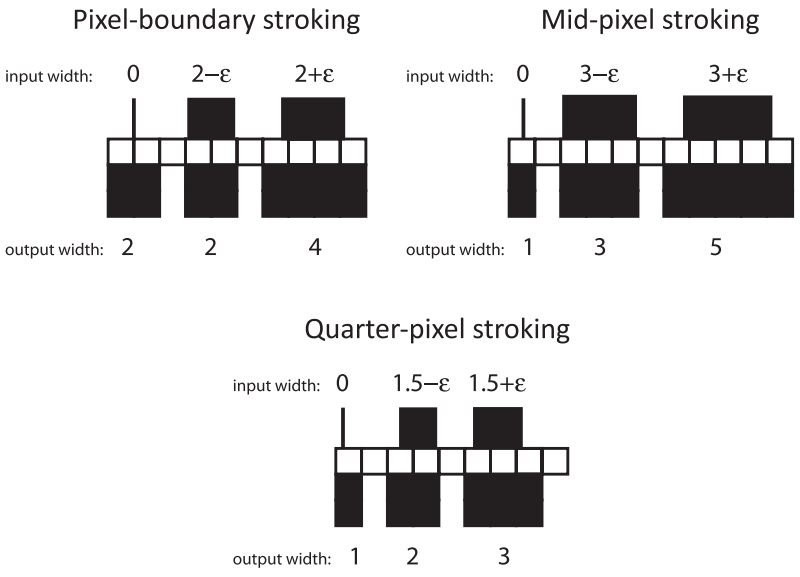


Figure 8: Quantization effects on continuous line widths when lines are centered at pixel edges, centers, and quarters. When stroking a horizontal/vertical line at pixel boundaries, only even pixel widths are possible. When stroking lines centered in the middle of pixels, only odd pixel widths are possible. Positioning lines at ¼ (or ¾) pixels allow for both even and odd pixel widths for lines in the rendered coordinate space.

---

[7] http://partners.adobe.com/public/developer/en/ps/sdk/5111.Stroke_Adj.pdf, "Emulation of the setstrokeadjust Operator" Technical Note #5111, 31 March 1992, Adobe Systems, San Jose, California.

Figure 9 demonstrates the difference between using and not using stroke adjustment. The left half of the figure does not use stroke adjustment. This causes the top line of the staff to be one (or possibly two) pixels thinner than the other lines in the staff since the vector-graphics lines can be positioned at random fractional pixel positions. The right-half of the image shows the result of applying stroke-adjustment by quantizing the line endpoint at quarter-pixel offsets in the rendering device before quantization takes place.

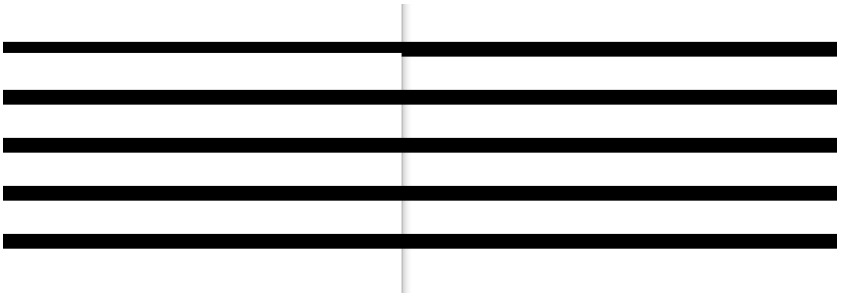


Figure 9: Example vector-graphic lines converted to bitmaps without stroke-adjustment on the left, and with stroke-adjustment on the right. In the left-hand staff lines, the top line is one pixel thinner due to quantization effects. This is compensated by the stroke adjustment process applied on the right.

Stroke-adjust placement of horizontal/vertical line endpoints can occur at four possible locations within the pixel as shown in Figure 10. The left hand of the figure references the origin of the pixel at the bottom left corner, while the right hand of the figure references the top left corner. When doing more sophisticated stroke adjustments, these four points may be utilized. For example in GhostScript's stroke-adjustment code, the left endpoint of horizontal lines are at the ¼ pixel position, while the right endpoint is at the ¾ pixel position. This is to ensure that lines shorter than one pixel are not quantized to be zero length.

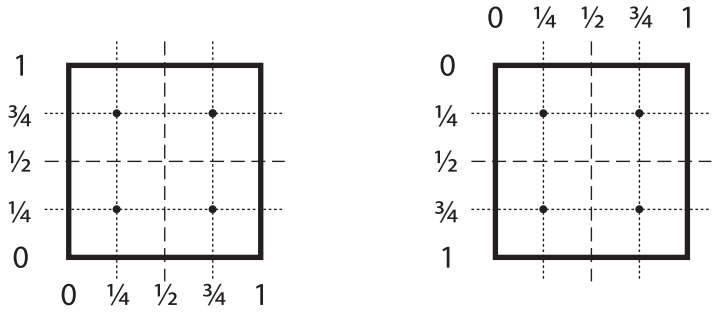


Figure 10: `setStrokeAdjust` pixel quantization locations within the rendering device's pixel boundary.

Stroke-adjust implementations are probably device dependent. As a guideline I compare against the method used in GhostScript, which is the primary open-source implementation of a PostScript vector-graphics to bitmap converter.[8] The source code for implementing stroke adjustment in GhostScript is located in `ghostpdl-9.06/gs/base`.[9] But this code is overly generalized to be immediately readable, so reverse-engineering was used instead to generate the following stroke-adjustment emulation.

The program *scrstaffq* described in the previous section will match the output from SCORE when comparing with 600 DPI bitmaps and when the stroke-adjust setting is turned off. If the stroke-adjust setting in SCORE is turned on, the pixel behavior will be slightly different. It is preferable to turn on the stroke-adjust setting in SCORE printing (it is turned on by default) to make staff lines quantize with uniform thickness when printing on paper or to a bitmapped image. The following program, called *scrstaffqq*, shows the final staff printing emulation program. This program calculates the continuous position of staves, then it applies a 4000 DPI quantization to match SCORE's printing behavior, and then it applies a 600 DPI (or any arbitrary rendering resolution) quantization plus quarter-pixel offsets to match the behavior of the stroke-adjust functionality usually included in SCORE EPS output.

scrstaffqq.pl

```
#!/usr/bin/perl
#
# Programmer:    Craig Stuart Sapp <craig@ccrma.stanford.edu>
# Creation Date: Mon Oct 15 09:18:12 PDT 2012
# Last Modified: Mon Nov 19 14:12:58 PST 2012
# Filename:      scrstaffqq
# Syntax:        perl 5
#
# Description: Print staff lines from SCORE PMX data, applying 4000 DPI
#    quantization (emulating printing method of SCORE), and then applying
#    stroke-adjust quantization (emulating stroke-adjust feature of bitmap
#    rendering device).
#
# Basic command-line options:
# -Q    == Turn off 4000-DPI quantization of coordinates.
# -S    == Turn off stroke-adjust quantization.
# -E    == Don't echo input SCORE PMX data in output content.
# -p    == Plain output: width, x1, y1, x2, y2 info for lines
# -f    == Flip origin to top left of page [using letter-sized paper (11")]
#
# Print parameters:
# -b #  == Set bottom margin (in inches, excluding extra 0.0625" offset).
# -l #  == Set left margin (in inches, excluding extra 0.025" offset).
# -s #  == Set page scaling (default 1.0, scaling excludes margin offsets).
# -d #  == Set DPI related to -w (line width) value.
# -w #  == Set line with in pixels of -d option's DPI value.
# -r #  == Set renderer DPI for use with stroke-adjust quantization.
# -o #  == Set the output DPI (usually equivalent to -r setting).
#
```

[8] http://en.wikipedia.org/wiki/Ghostscript, http://www.ghostscript.com/download, and http://www.gnu.org/software/ghostscript .

[9] http://downloads.ghostscript.com/public/ghostpdl-9.06.tar.gz

```
use strict;
use POSIX;
use Getopt::Long;

my $noquantize     = 0;    # used with -Q option
my $nostrokeadjust = 0;    # used with -S option
my $echoQ          = 0;    # used with -E option
my $plain          = 0;    # used with -p option
my ($BM, $LM, $S, $DPI, $LINE_width, $rDPI, $oDPI, $debugQ, $originflipQ);
my $strokeadjustCodeQ = 0; # used with --stroke-adjust option
Getopt::Long::Configure("bundling");
GetOptions (
   'Q|no-quant'   => \$noquantize,
   'S|no-stroke'  => \$nostrokeadjust,
   'p|plain'              => \$plain,
   'f|origin-flip'      => \$originflipQ,
   'E|no-echo'          => \$echoQ,
   'b|B|bottom-margin:f'=> \$BM,
   'l|L|left-margin:f'  => \$LM,
   's|scale|size:f'     => \$S,
   'd|dpi|DPI:i'  => \$DPI,
   'o|output-dpi|oDPI:i'=> \$oDPI,
   'r|rdpi|rDPI|RDPI:i' => \$rDPI,
   'w|lw|line-width:i'  => \$LINE_width,
   'stroke-adjust'      => \$strokeadjustCodeQ,
   'debug'              => \$debugQ
);
$echoQ = !$echoQ; # reverse truth state since input is "not echo".

# Set default command-line options for SCORE print options:
$BM   = 0.75   if $BM   =~ /^\s*$/;  # SCORE bottom-margin setting
$LM   = 0.50   if $LM   =~ /^\s*$/;  # SCORE left-margin setting
$S    = 1.00   if $S    =~ /^\s*$/;  # SCORE page scale setting
$rDPI = 600    if $rDPI =~ /^\s*$/;  # Actual bitmap rendering DPI
$DPI  = $rDPI  if $DPI  =~ /^\s*$/;  # SCORE target rendering DPI
$oDPI = $rDPI  if $oDPI =~ /^\s*$/;  # Final output rendering DPI
$LINE_width = int(4 * $DPI / 600.0 + 0.5);  # if $LINE_width  =~ /^\s*$/;
$LINE_width = 1 if $LINE_width == 0;
my $PAGEHEIGHT = 11.0; # page height in inches (used with -f option).

# Other command-line options:
my $quant4000 = !$noquantize;      # simulate SCORE EPS quantization at 4000
DPI
my $strokeadj = !$nostrokeadjust;  # simulate SCORE STROKEADJUST parameter

# SCORE print menu variables (most now set via command-line options):
# $S = 1.0;                        # global music scaling
$LM            = $LM * 72.0;       # left margin
$BM            = $BM * 72.0;       # bottom margin
# $DPI         = 600;              # target print resolution
# $LINE_width  = 4;                # pixel width of line strokes
my $small_line = $LINE_width - 1;  # pixel width of staff lines when P5 < 0.65
$small_line = 1 if $small_line == 0;
my $StrokeBig  = $LINE_width / $DPI * $oDPI;
my $StrokeSmall= $small_line / $DPI * $oDPI;
```

```
# Constants, expressed in points:
my $Lx         = 0.025   * 72.0;   # left margin buffer
my $Bx         = 0.0625  * 72.0;   # bottom margin buffer
my $Len        = 7.5     * 72.0;   # default full length of staff
my $Step       = 0.04375 * 72.0;   # vertical diatonic step size
my $Vx         = 0.7875  * 72.0;   # default spacing of successive staves

my $dpi72to4000  = 4000.0 / 72.0;  # conversion factor from points to 4000 DPI
my $hoffset4000 = ($LM + $Lx) * $dpi72to4000;           # default is 2100
my $voffset4000 = ($BM + $Bx + 6 * 72) * $dpi72to4000;  # default is 27250

# 4000-quantize new origin (6" above bottom left margin origin)
my $hoffset4000q = int($hoffset4000);
my $voffset4000q = int($voffset4000);

#$Stroke += 0.0007206;    # Match line thickness behavior in SCORE.
#$Stroke *= $dpi72to4000; #   In practice this small offset is not necessary.
my  $LW = $StrokeBig;     # Variables for keeping track of stroke width which
my  $oldLW = $StrokeBig;  #   is needed since gsave/grestore are not used.

if (!$plain) {
   print "%!PS-Adobe-2.0 EPSF-1.2\n"; # print PostScript marker
   # print PostScript functions:
   print "/m {moveto} def\n";
   print "/l {lineto} def\n";
   print "/s {stroke} def\n";
   print "/lw {setlinewidth} def\n";
   print "/tr {translate} def\n";
   if ($strokeadjustCodeQ) {
      print <<"EOT";
/setstrokeadjust where
{ pop true setstrokeadjust }
{ /m { transform .25 sub round .25 add exch .25 sub round .25 add exch
itransform  moveto } bind def
/l { transform .25 sub round .25 add exch .25 sub round .25 add exch
itransform  lineto } bind def } ifelse
EOT
   }

   print "\ngsave\n";
   print 72.0/$oDPI, " dup scale\n";
   print "$LW lw\n";
}

while (my $line = <>) {
   next if $line !~ /^8/;
   printStaffObject($line);
}

if (!$plain) {
   print "grestore\n";
   print "showpage\n";
}

exit(0);

##############################################################################
```

```
##############################
##
## printStaffObject -- Place a staff on the page based on its SCORE
##      PMX data.
##

sub printStaffObject {
   my ($line) = @_;
   chomp $line;
   my @data   = split(/\s+/, $line);
   my ($P1, $P2, $P3, $P4, $P5, $P6) = @data;
   $P1 *= 1; $P2 *= 1; $P3 *= 1; $P4 *= 1; $P5 *= 1; $P6 *= 1;
   $P5 =   1.0 if $P5 == 0.0;
   $P6 = 200.0 if $P6 == 0.0;
   my $width  = $S  * ($Len*($P6-$P3)/200.0);
   my $hlpos  = $LM + $Lx + $S * ($Len*$P3/200.0);
   my $vpos   = $BM + $Bx + $S*(($P2-1)*$Vx+$P4*$P5*$Step);
   my $lspace = $Step * 2 * $P5 * $S;  # spacing between staff lines

   # scale to 4000-DPI coordinates (from 72-DPI coordinates):
   $hlpos  = $hlpos  * $dpi72to4000;
   $vpos   = $vpos   * $dpi72to4000;
   $width  = $width  * $dpi72to4000;
   $lspace = $lspace * $dpi72to4000;

   # print the original SCORE PMX data for the staff:
   print "%SCORE%", join(" ", @data), "\n" if $echoQ;

   # if the stroke width has changed, print it.  This code is hard-coded
   # and should be generalized.  But 20.03 is equal to 3 pixels at 600 dpi
   # (one less than default staff line width), plus a small extra amount.
   $LW = $StrokeBig;
   $LW = $StrokeSmall if $P5 < 0.65;
   if (!$plain) {
      if ($LW != $oldLW) {
         printf("    %.4lf lw\n", $LW);
         $oldLW = $LW;
      }
   }

   # print the staff on the page according to the PMX parameters:
   printStaffLines(5, $hlpos, $width, $vpos, $P5);
}



##############################
##
## printStaffLines -- print the specified number of lines with the given
##     vertical spacing between lines.
##

sub printStaffLines {
   my ($count, $hlpos, $width, $vbottom, $P5) = @_;

   my ($vpos, $vposq);
```

```
my $vorigin = $vbottom;
my $hrposq;

# The bottom staff line of the staff is at vertical unit "3" in SCORE.
# Shift the origin down 3 steps from the bottom line of the staff.
# the default diatonic-step size is 175 units at 4000 DPI (3.15pt)
my $diatonicstep = 175 * $P5;
$vorigin = $vorigin - 3.0 * $diatonicstep;

# print staff lines at diatonic steps 3, 5, 7, 9, 11:
for (my $i=3; $i<=11; $i+=2) {

   # variables for quantized versions of values:
   my $hlposq   = $hlpos;
   my $vbottomq = $vbottom;
   my $widthq   = $width;

   # compensate for quantization problems near integers:
   $hlposq -= 0.001 if $hlposq < 0;
   $hlposq += 0.001 if $hlposq > 0;
   if ($quant4000) {
      $hlposq    = int($hlposq);
      $widthq    = int($widthq);
      $vbottomq  = int($vbottomq);
   }

   $hrposq = $width + $hlpos;

   # compensate for quantization problems near integers:
   $hrposq -= 0.0001 if $hrposq < 0;
   $hrposq += 0.0001 if $hrposq > 0;
   $hrposq = int($hrposq) if $quant4000;

   $vpos = $vorigin + $i * $diatonicstep;
   $vposq = $vpos;
   # compensate for quantization problems near integers:
   $vposq -= 0.0001 if $vposq < 0;
   $vposq += 0.0001 if $vposq > 0;
   $vposq = int($vposq) if $quant4000;

   # avoid small numbers such as -1e8 when not quantizing:
   if (!$quant4000) {
      $hlposq = 0 if $hlposq =~ /e/i;
      $hrposq = 0 if $hrposq =~ /e/i;
      $vposq  = 0 if $vposq  =~ /e/i;
   }

   if ($strokeadj) {
      $hlposq = setStrokeAdjust($hlposq, 4000, $rDPI, $oDPI, +1);
      $hrposq = setStrokeAdjust($hrposq, 4000, $rDPI, $oDPI, -1);
      $vposq  = setStrokeAdjust($vposq,  4000, $rDPI, $oDPI, -1);
   } else {
       $hlposq = $hlposq / 4000 * $oDPI;
       $hrposq = $hrposq / 4000 * $oDPI;
       $vposq  = $vposq  / 4000 * $oDPI;
   }
```

```
      if ($originflipQ) {
         $vposq = $PAGEHEIGHT * $oDPI - $vposq;
      }

      if ($plain) {
         print "$LW\t$hlposq\t$vposq\t$hrposq\t$vposq\n";
      } else {
         print " $hlposq $vposq m\n";
         print " $hrposq $vposq l\n";
      }
   }
   print " s\n" if !$plain;
}



##############################
##
## setStrokeAdjust -- Quantize a coordinate to the nearest pixel boundary
##      in the target rendering resolution plus a quarter-pixel offset.
##   $value       = Input value to quantize.
##   $inputscale  = Usually SCORE's 4000-DPI coordinate quantization.
##   $renderDPI   = Rendering DPI, usually 600 DPI.
##   $outputscale = Target DPI for rendered bitmap of page, usually 600 DPI.
##   $direction   = Whether or not to reflect axis before quantizing.
##      direction  = +1 : Horizontal coordinate (left end of horizontal line)
##      direction  = -1 : Vertical coordinate (bitmap origin at top of page)
##                        also used for right end of horizontal line.

sub setStrokeAdjust {
   my ($value, $inputscale, $renderDPI, $outputscale, $direction) = @_;

   # convert to rendering coordinate space:
   my $devicepos = $direction*$value/$inputscale*$renderDPI;

   # quantize to nearest pixel boundary + 1/4 pixel
   # (not exactly nearest, but this emulates better):
   $devicepos = floor($devicepos) + 0.25;

   # convert to the output coordinate space
   # (possibly different from rendering or input DPI).
   my $newvalue = $devicepos/$renderDPI*$outputscale;

   $newvalue = $direction*$newvalue;

   # This gives minimally better results for some reason,
   # but could be removed for elegance.
   if (abs($newvalue - int($newvalue) - 0.75) < 0.0001) {
      $newvalue -= 0.50;
   }

   if ($debugQ) {
      print "%VALUE: $value => $newvalue\n";
   }

   return $newvalue;
}
```

The *scrstaffqq* program does a relatively good job of emulating the stroke-adjust functionality of GhostScript. Only a 1-pixel difference in the vertical placement of one staff line can be see in the difference images on the right side of Figure 11. This difference is due either to a quantization bug in *scrstaffqq* or it does not completely emulate GhostScript's stroke-adjusting system.

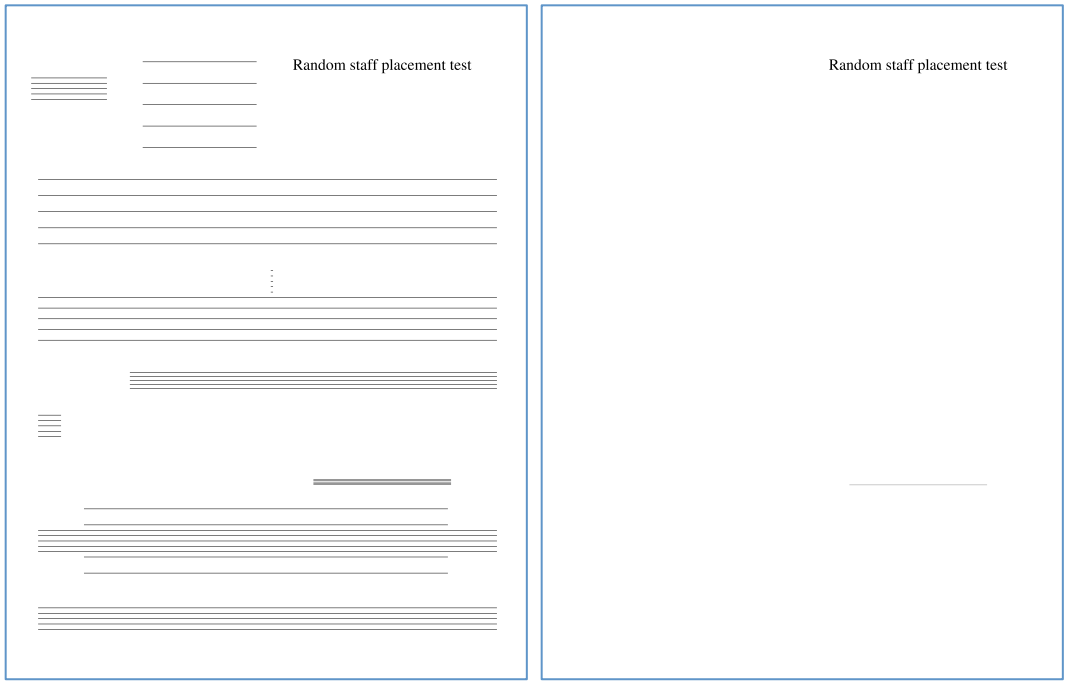


Figure 11: Evaluation of the accuracy for *scrstaffqq* to match the pixel placement of staff lines, compared to converting SCORE EPS files into TIFF images with GhostScript. Image on the left shows the original image, while the image on the right is the difference between the SCORE EPS and the simulated EPS generated by *scrstaffqq*. Compare to **Figure 5** on page 22.

10 Pixel localization of staves in TIFF images

As discussed in Section 1 (starting on page 19), EPS output from SCORE can be converted into bitmapped images, such as the TIFF images used for evaluating staff-placement algorithms in this document. The *scrstaffqq* program listed in the previous section can be used to predict the exact pixel placement of staff lines in these EPS conversions into TIFF images using GhostScript to render the PostScript code into bitmaps. The `-p` and `-f` options can be used together to output the pixel-based locations of staff lines in the resulting TIFF image. The `-p` option is used to output a "plain" listing of the instructions to draw staff lines. The `-f` option is used to flip the origin so that the top left corner of the TIFF image is the origin (bitmapped images typically are defined with the top left corner of the image used as the origin, while PostScript defines the bottom left corner of the page as the origin). Here is example input and output data for the 8th staff in the `random.pmx` example from Figure 4 on page 22:

```
echo "8 8 101.45 0 .00 102.36" | ./scrstaffqq -pf

%SCORE%8 8 101.45 0 .00 102.36
4     2597.25     2805.75     2618.25     2805.75
4     2597.25     2752.75     2618.25     2752.75
4     2597.25     2700.75     2618.25     2700.75
4     2597.25     2647.75     2618.25     2647.75
4     2597.25     2595.75     2618.25     2595.75
```

The output from *scrstaffqq* contains the position information for the five lines of the staff from the bottom up, as well as the line width for stroking these lines. The five columns of numbers in the data of the above example:

1. Line width in pixels.
2. Left horizontal position of line (all in pixels).
3. Left vertical position of line (origin at top left corner of image when –f option is used).
4. Right horizontal position of line.
5. Right vertical position of line (which should be the same as column #3).

The left and right horizontal pixel positions of the lines can be directly read from data. For example each line starts at horizontal position 2597.25 pixels (column #2) and goes to horizontal position 2618.25 (column #4). The fractional positions are due to the stroke-adjust processing. Drop the fractional part of the pixel number to determine the final position in the bitmap. So the staff lines start at horizontal pixel 2597 and go through pixel 2618.

To determine the starting/ending points vertically, half of the line width (column #1) needs to be subtracted/added from the vertical position of the line (columns #3 and #5):

Top vertical pixel = `floor(#3 - #1/2)`

Bottom vertical pixel = `floor(#3 + #1/2)`

In this example the top pixel is floor(2805.75 – 4/2) = floor(2803.75) = 2803. The bottom vertical pixel in the staff line is floor(2805.75 + 4/2) = floor(2805.75) = 2805. Figure 12 shows the verification of these calculations by examining the rendered TIFF image of the this particular staff line in Adobe Photoshop:

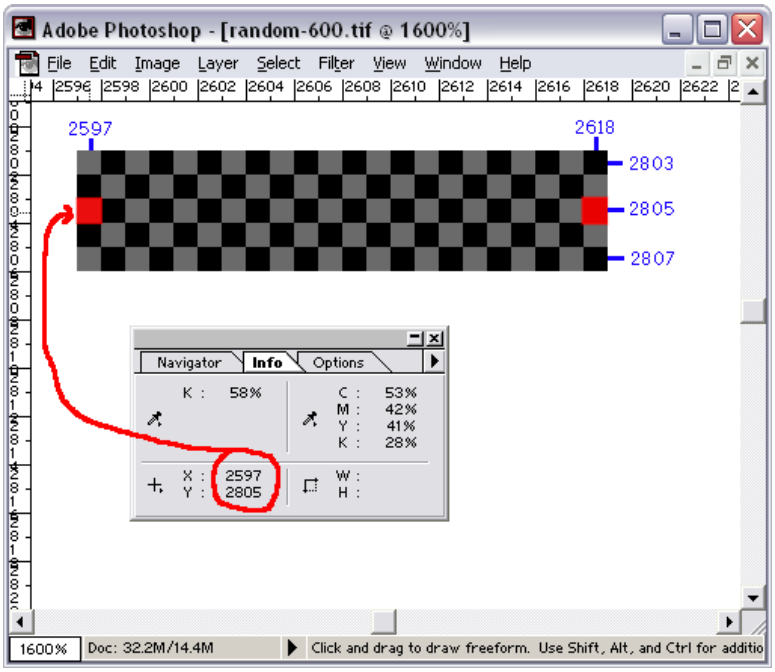


Figure 12: Bottom line of example staff viewed as a rendered TIFF bitmap in Adobe Photoshop. The two red pixels at both ends of the staff line are the coordinates that specify the staff line in the output data for the staff line which is calculated by *scrstaffq* .

The pixel boundaries of the entire staff can also be calculated from the output of "**`scrstaffqq -pf`**". In this case the left/right positions are the same as all individual staves, while the top pixel positions are the top vertical pixel position of the top staff line, and the bottom pixel position of the staff is the bottom vertical pixel position of the bottom staff line:

Top pixel of staff: floor(2595.75 – 4/2) = floor(2593.75) = 2593
Bottom pixel of staff: floor(2805.75 + 4/2) = floor(2807.75) = 2807

Thus top left and bottom right coordinates of the staff in the TIFF image are:

Top left position: (2597, 2597)
Bottom right position: (2618, 2807)

And the horizontal and vertical width of the full staff (a very short staff) is:

Horizontal width: 2618 – 2597 + 1 = 22 pixels
Vertical width: 2807 – 2597 + 1 = 215 pixels

The following PERL script, called *hilitestaff*, can be used to highlight staves in TIFF images generated from SCORE EPS files. The *hilitestaff* program takes input data generated by "**scrstaffqq -pf**" as just described. The *hilitestaff* program takes the individual staff lines and groups them into staves to calculate the bounding box within the TIFF images for each staff on the page.

hilitestaff.pl

```
#!/usr/bin/perl
#
# Programmer:    Craig Stuart Sapp <craig@ccrma.stanford.edu>
# Creation Date: Tue Nov 20 06:28:41 PST 2012
# Last Modified: Tue Nov 20 16:20:14 PST 2012
# Filename:      hilitestaff
# Syntax:        perl 5
#
# Description:   Input staff-line position data from "scrstaffqq -pf" and
#                a TIFF image of the graphical music.  Outputs a TIFF image
#                which highlights all staves.
# Options:
#           -r [0..255] = Amount of red in highlight
#           -g [0..255] = Amount of green in highlight
#           -b [0..255] = Amount of blue in highlight
#           -o [0.0..1.0] = Opacity

use strict;
use POSIX;
use Getopt::Long;

my ($red, $green, $blue, $alpha) = (255, 0, 0, 0.5);
my $randomQ     = 0;  # highlight staves with random colors.
my $system      = 1;  # number of staves in a system
my $dimensionsQ = 0;  # print only the positions of highlighting rectangles.
my $commandQ    = 0;  # print final command without running it.
my $oneQ        = 0;  # add extra one-pixel border around staves
my $numberQ     = 0;  # print staff number above each staff.
my $aboveQ      = 0;  # place staff number to left of staff box
Getopt::Long::Configure("bundling");
GetOptions (
   'r|red:i'                    => \$red,
   'g|green:i'                  => \$green,
   'b|blue:i'                   => \$blue,
   't|transparency|a|alpha:i'   => \$alpha,
   's|system:i'                 => \$system,
   'random'                     => \$randomQ,
   'd|dimensions'               => \$dimensionsQ,
   'c|command'                  => \$commandQ,
   'n|number'                   => \$numberQ,
   '1'                          => \$oneQ,
   'a|above'                    => \$aboveQ
);

$system = 1 if $system < 1;

$red   = 255 if $red   > 255;
$blue  = 255 if $green > 255;
```

```
$green = 255 if $blue  > 255;
$red   =   0 if $red   < 0;
$blue  =   0 if $green < 0;
$green =   0 if $blue  < 0;
$alpha =   0 if $alpha < 0;
$alpha =   1 if $alpha > 1;

if ($dimensionsQ) {
   die "Usage $0 -d input.txt" if @ARGV < 1;
} else {
   die "Usage $0 input.txt input-image output-image" if @ARGV != 3;
}

my $inputdatafile = $ARGV[0];
my $inputimage    = $ARGV[1];
my $outputimage   = $ARGV[2];

my @rectangles = getStaffDimensions($inputdatafile);

if ($dimensionsQ) {
   print join("\n", @rectangles), "\n";
   exit(0);
}

my $options = "-strokewidth 0";
$options .= " -type Palette" if $outputimage =~ /\.tiff?$/i;
$options .= " -pointsize 150" if $numberQ;
$options .= " -fill \"rgba($red,$green,$blue,$alpha)\"" if !$randomQ;

for (my $i=0; $i<@rectangles; $i++) {
   my $rect = $rectangles[$i];
   if ($randomQ) {
      $red   = int(rand(256 - 100) + 50);
      $green = int(rand(256 - 100) + 50);
      $blue  = int(rand(256 - 100) + 50);
      $options .= " -fill \"rgba($red,$green,$blue,$alpha)\"";
   }
   if ($numberQ and !$randomQ) {
      $options .= " -fill \"rgba($red,$green,$blue,$alpha)\"";
   }
   $options .= " -draw \"rectangle $rect\"";
   if ($numberQ) {
      $rect =~ /^(\d+),(\d+)/;
      my ($xval, $yval) = ($1, $2);
      if ($aboveQ) {
         $yval += -50;
      } else {
         $xval += -200;
         $yval += 100;
      }
      my $number = $i+1;
      if ($system > 1) {
         # number from the top down for system groupings.
         $number = @rectangles - $i;
      }
      $options .= " -fill red -draw \"text $xval,$yval '$number'\"";
   }
```

```
}

my $command = "convert $inputimage $options $outputimage";

print "$command\n";
exit(0) if $commandQ;
`$command`;

exit(0);

################################################################################

##############################
##
## getStaffDimensions -- read every 5 lines of numbers in the input data
##   and extract the position of the staff from these values.
##

sub getStaffDimensions {
   my ($filename) = @_;
   open (FILE, $filename) or die "Cannot open $filename for reading.\n";
   my $line;
   my @staff;
   my @output;
   my @data;
   while ($line = <FILE>) {
      chomp $line;
      $line =~ s/\s+$//;
      $line =~ s/^\s+//;
      next if $line !~ /^[\d\.]/;
      @data = split(/\s+/, $line);
      next if @data != 5;
      $staff[@staff] = $line;
      if (@staff == 5 * $system) {
         $output[@output] = staffDimension(@staff);
         @staff = ();
      }
   }
   return @output;
}



##############################
##
## staffDimension -- Extract dimension of staff from individual staff-line
##     vector graphics descriptions.
##
## Example input data to function:
##
## Width X1      Y1       X2       Y2
## 4  765.25      5561.75     4333.25     5561.75
## 4  765.25      5403.75     4333.25     5403.75
## 4  765.25      5246.75     4333.25     5246.75
## 4  765.25      5088.75     4333.25     5088.75
## 4  765.25      4931.75     4333.25     4931.75
##
```

```
sub staffDimension {
   my (@staff) = @_;
   my $size = @staff;
   my @bottomline = split(/\s+/, $staff[0]);
   my @topline    = split(/\s+/, $staff[$size-1]);
   my $width  = $bottomline[0];
   my $xval1  = floor($bottomline[1]);
   my $xval2  = floor($bottomline[3]);
   my $yval1  = floor($topline[2] - $width/2.0);
   my $yval2  = floor($bottomline[2] + $width/2.0);
   if ($oneQ) {
      $xval1 += -1;
      $yval1 += -1;
      $xval2 += +1;
      $yval2 += +1;
   }
   return "$xval1,$yval1 $xval2,$yval2";
}
```

Figure 13 show the result of *hilitestaff*. First the PMX data is processed with *scrstaffqq* (using the `-pf` options). Then the resulting stroke-adjusted vector-graphics information is given to *hilitestaff* which colors in the rectangular region covered by each staff. Several options to *hilitestaff* are used in Figure 13: `--random` is used to color each staff differently. The `-1` option places an extra one-pixel border around the staff (which you can see when zooming in), the `-n` option is used to number each staff (in the order that they are found in the PMX data, not the actual P2 staff number), and `-a` is used to place the staff number above the staff rather than to left of the staff.

```
./scrstaffqq -pf random.pmx > random.vec

./hilitestaff -1na --random random.vec \
      input.tif output.tif
```

```
8  1   0
8  2   0    11
8  4 120     0    .25  180.00
8  5   0     0    .00   10.00
8  6  20   -23   3.00  178.60
8  6  40     0    .75
8  7   0     0   2.00
8  8 101.45  0    .00  102.36
8  9   0     0   3.00  100.00
8 10 100    -6   3.00
8 11  45.63  0   4.00   95.24
8 12  -3     0    .00   30.00
t 12 111.01 14   1.00    1.327
_00Random staff placement test
```

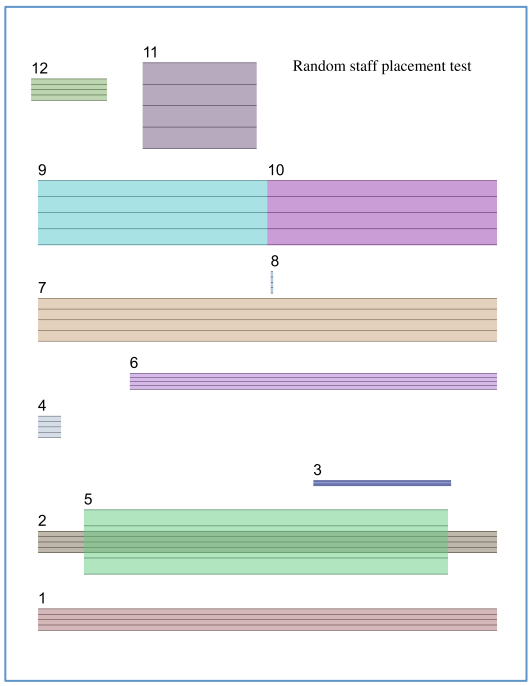


Figure 13: Example PMX data and commands (left) which are used to highlight staves in the TIFF image (right) created with GhostScript from a SCORE EPS file. The –n option to hilitestaff places a number above each staff (numbered in the order they are found in the PMX data, not the staff number in the PMX data). The – –random option is used to hightlight with a random color for each staff.

By default, *hilitestaff* will highlight staves red. But the color can be controlled with `-r`, `-g`, and `-b`, which can control the red/green/blue color channels using values in the range from 0–255. In addition the opacity of the highlighting can be controlled with the `-o` option followed by a number in the range from 0–1. The option "`-o 0`" will make the highlighted regions invisible, and "`-o 1`" will make the highlighted regions completely opaque, blocking the view of the staves underneath. The default value is "`-o 0.5`".

Figure 14 shows highlighting of staves on a real page of graphical music notation (complete PMX data for this example can be found in Appendix V starting on page 88). When the `-n` option is used, the staves will be numbered in the order in which they are found in the PMX data, so notice that the numbering in the left image of the figure start at the bottom of the page and go upwards, following the actual P2 staff numbers in the PMX data (by coincidence, but usually the default ordering in PMX data). For the right-hand image, the "`-s 2`" option was used to group every two staves into a single highlighted system. For variable-stave systems, a more sophisticated parsing of the PMX data would be required, since system groupings must be implicitly derived from barline information. When the `-s` option is used to group staves into systems, the numbering is reversed so they will typically will flow from top to bottom on the page.

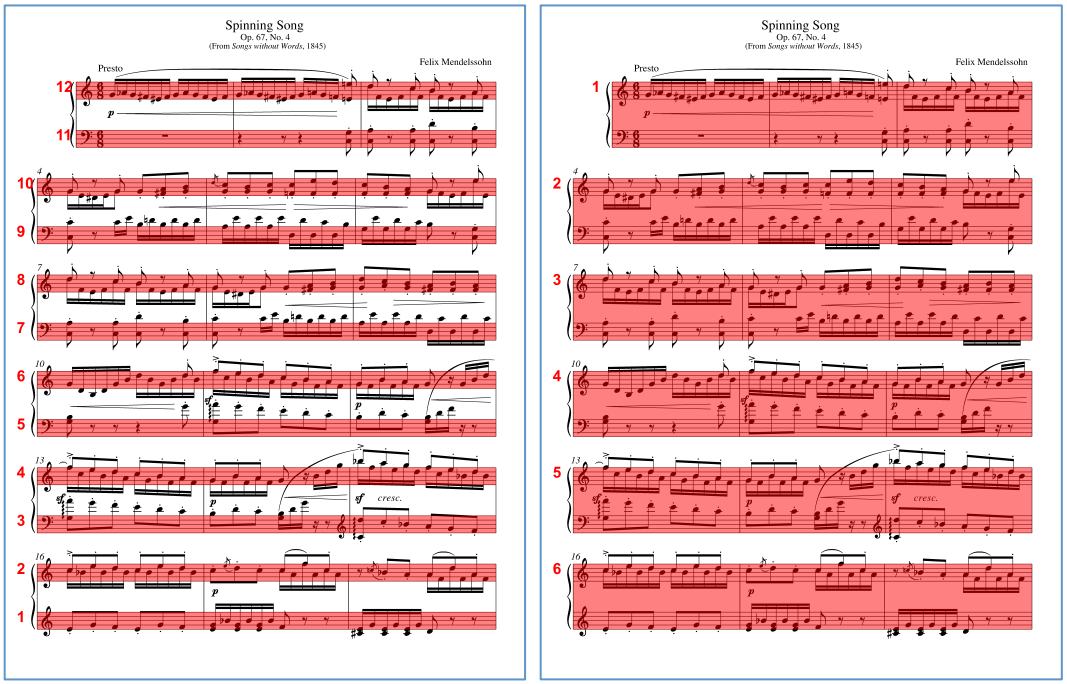


Figure 14: Staff highlighting in actual music using the *hilitestaff* program. The image on the left was processed with the command "`hilitestaff –n spin1.vec spin1.tif spin1out.tif`". The image on the left was created with the command "`hilitestaff –n –s2 spine1.vec spin1.tif spine2out.tif`" which highlights pairs of staves when adding the –s 2 option. Note that when highlighting multiple staves per system, the –n option will number from the top of the page down. See Appendix V starting on page 88 for the PMX data of this music.

The *hilitestaff* program can also be used to display the exact pixel regions in the bitmapped notation which are used to draw a triangle. This can be done by using the `-d` option to list the dimensions of each rectangular region. Below are the pixel coordinates for both

the left and right sides of Figure 14. First the staff line information must be extracted from the PMX data using *scrstaffqq*:

```
./scrstaffqq -pf spin1.pmx > spin1.vec
```

Then the *hilitestaff* script can be used to list the rectangular regions for each staff:

```
./hilitestaff -d spin1.vec
```

```
315,5942 4814,6114
315,5470 4814,5642
315,4997 4814,5169
315,4525 4814,4697
315,4052 4814,4224
315,3580 4814,3752
315,3107 4814,3279
315,2635 4814,2807
315,2162 4814,2334
315,1690 4814,1862
697,1217 4814,1389
697,743 4814,915
```

Each line contains two pixel coordinates in the image: the first coordinate is the upper left corner of the staff, and the second coordinate is the lower right coordinate of the staff. So the first (bottom) staff's upper-left corner is at horizontal pixel 315, vertical pixel 5942; while the lower-right coordinate is (4814, 6114). The origin of the image is (0,0) for the top left pixel in the image.

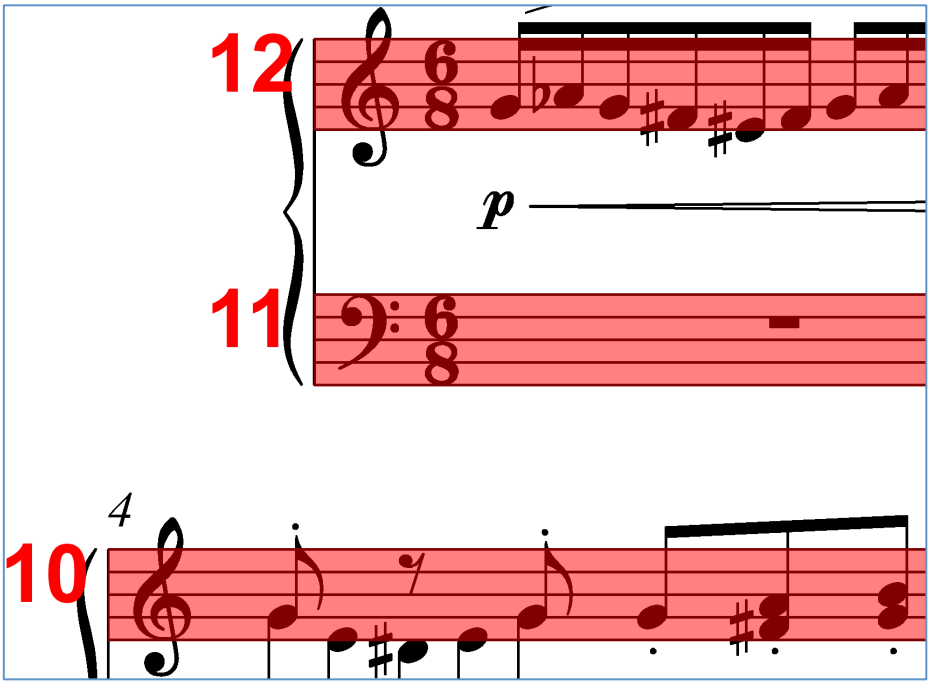


Figure 15: Zoom-in on a region from **Figure 14** which shows the staff bounding boxes in more detail.

The pixel coordinate boundaries of the system can be listed by adding "`-s 2`" in this case:

```
./hilitestaff -d -s2 spin1.vec
```

```
315,5470 4814,6114
315,4525 4814,5169
315,3580 4814,4224
315,2635 4814,3279
315,1690 4814,2334
697,743 4814,1389
```

Note that the first entry now consists of the top left corner of the second staff in the single-staff listing, and then the bottom right corner of the first staff. Highlighting the notation image is done with the ImageMagick program *convert* (which is also used in previous sections). The `-c` option can be added to display the *convert* command which would be run. For example, here is the convert command used to highlight the six systems on the right side of Figure 14:

```
./hilitestaff -cns2 spin1.vec
```

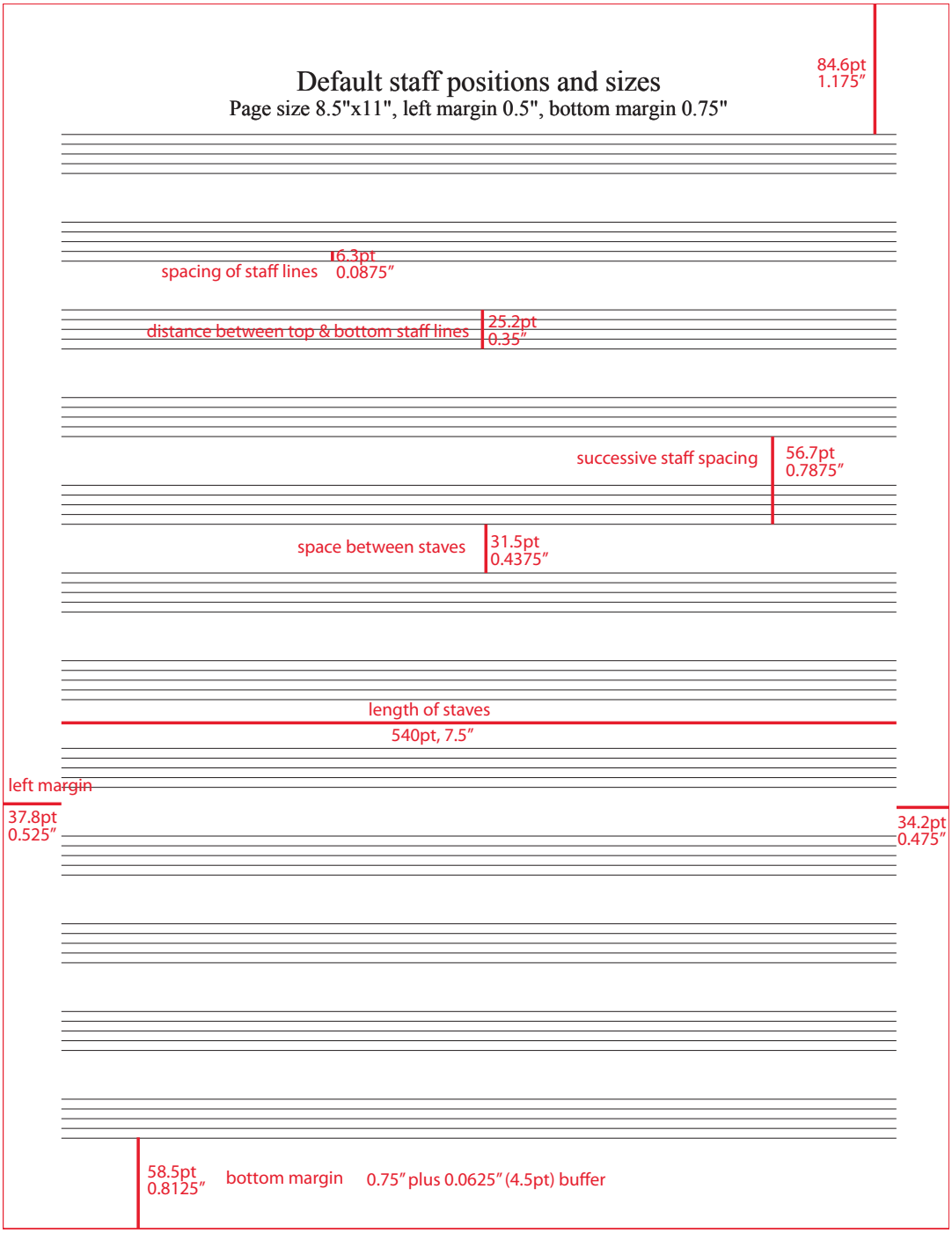
```
convert  -strokewidth 0 -pointsize 150 \
   -fill "rgba(255,0,0,0.5)"  -draw "rectangle 315,5470 4814,6114" \
   -fill red -draw "text 115,5570 '6'" \
   -fill "rgba(255,0,0,0.5)" -draw "rectangle 315,4525 4814,5169" \
   -fill red -draw "text 115,4625 '5'" \
   -fill "rgba(255,0,0,0.5)" -draw "rectangle 315,3580 4814,4224" \
   -fill red -draw "text 115,3680 '4'" \
   -fill "rgba(255,0,0,0.5)" -draw "rectangle 315,2635 4814,3279" \
   -fill red -draw "text 115,2735 '3'" \
   -fill "rgba(255,0,0,0.5)" -draw "rectangle 315,1690 4814,2334" \
   -fill red -draw "text 115,1790 '2'" \
   -fill "rgba(255,0,0,0.5)" -draw "rectangle 697,743 4814,1389" \
   -fill red -draw "text 497,843 '1'"
```

Summary:

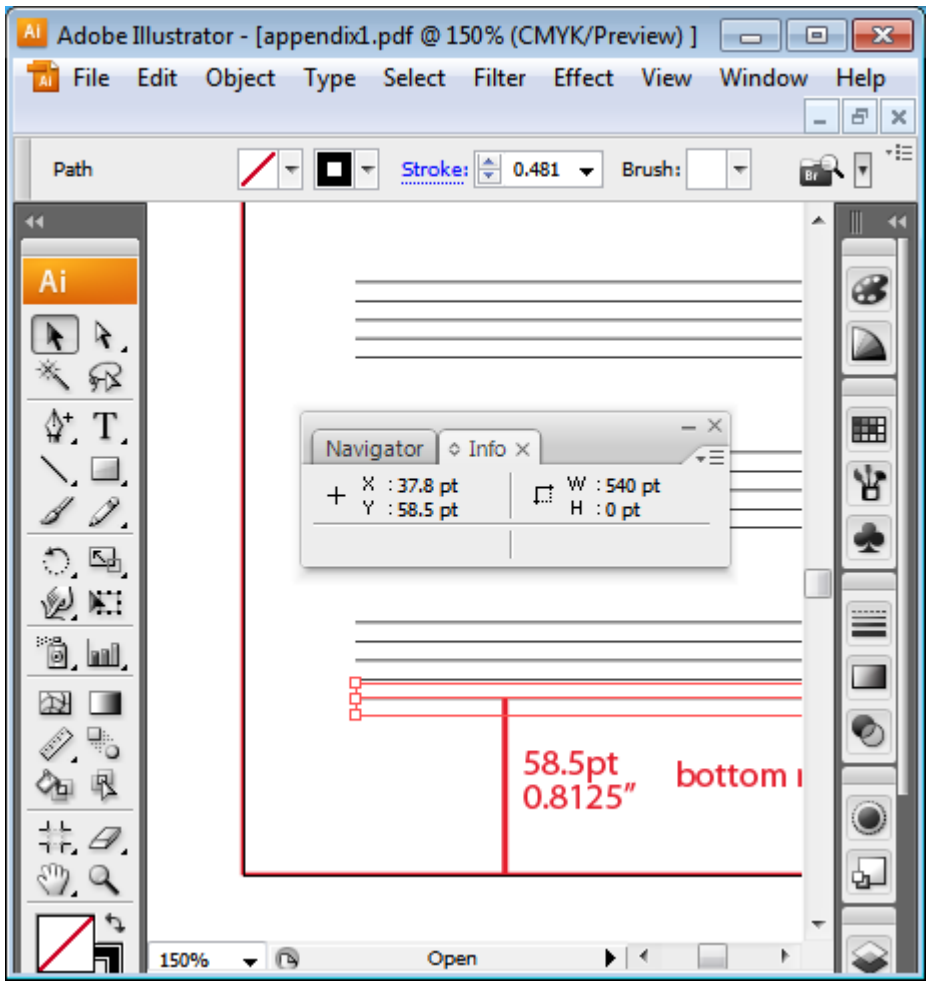
The *scrstaffqq* and *hilitestaff* programs can form the basis for more elaborate processing of staves in graphic images created from SCORE EPS files. They provide pixel-accurate bounding box information for any staff on the page. Note that the calculations do not involve examining the actual image, or utilizing other graphics software such as Ghost-Script. They only rely on the SCORE PMX data to calculate staff positions in a bit-mapped image of the EPS page. This allows the pixel-location algorithms illustrated in *scrstaffqq* and *hilitestaff* to be built into any stand-alone and portable code. The *scrstaffqq* program demonstrates how to extract stroke-adjusted vector graphics information for each staff line, and *hilitestaff* demonstrates how to do minimal processing to convert this information into pixel bounding boxes for all staves/systems on a page. The concepts illustrated in these two programs can also be extended to identifying the bounding box of any measure on the page, as well as the placement of any SCORE graphical object on the page. See the code at the end of Appendix III for a C implementation of the *scrstaffqq* and *hilitestaff* PERL scripts.

Appendix I: Staff/Margin measurements in Illustrator

The following figure shows measurements taken on a page with staves in their default positions and at their default size. See Figure 2 on page 13 for the SCORE PMX data used to create this page. Measurements are taken from the middle of staff lines and do not include the stroke-width applied to the lines.



The above sample page was measured and marked up in Adobe Illustrator:



To measure in Adobe Illustrator, select the measure tool which looks like a ruler rotated 45° from horizontal (the 10th tool down in the toolbar at the left in the above display). This will cause the measuring window to be displayed (small window shown in center of above figure). For example, the bottom staff has been selected, and the measure window states that the left side of the staff line is at horizontal position 37.8pt and vertical position 58.5pt on the page (in reference to the bottom left corner of the page. Likewise, the width of the staff line is 540pt, and the height is 0pt. The visual height of the line is controlled by the stroked line at its edges. In this case the stroke width is 0.481pt (actually 0.4807206 in the EPS code), which is visible at the top center of the main window.

Appendix II: 1000 randomly placed staves

The following PMX data for 1000 randomly generated staves was used to evaluate 4000-DPI quantization effects in Section 8.1 starting on page 27.

```
8.0 11.0 6.198888 9.573973 0.283635 168.128403
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8.0 6.0 137.013641 6.403788 2.209637 177.147659
8.0 11.0 58.888359 -5.799335 2.723095 121.644852
8.0 8.0 83.874039 -9.587542 1.607307 198.448700
8.0 5.0 118.649696 4.666414 2.544294 156.736053
8.0 1.0 22.970961 9.541767 2.370384 93.362068
8.0 8.0 104.275040 -9.651664 1.951182 176.971146
8.0 1.0 57.301044 5.177618 1.143156 89.481674
8.0 2.0 106.074234 -6.134956 1.606160 173.772705
8.0 10.0 158.622559 7.788235 2.450329 162.144104
8.0 4.0 8.283471 1.655901 1.102729 166.090622
8.0 1.0 62.269833 -1.575273 0.529536 63.905930
8.0 10.0 102.355324 -8.824838 2.059513 181.125565
8.0 1.0 26.162342 2.579809 0.119009 64.991302
8.0 3.0 11.814712 7.149282 0.465376 95.674294
8.0 2.0 13.881954 -5.795333 2.183232 70.238258
8.0 7.0 13.589021 -0.181602 2.743708 28.936586
8.0 7.0 112.356483 -7.477275 0.094167 122.373634
8.0 10.0 66.533630 -7.068519 1.585504 77.184113
8.0 7.0 26.510862 3.849252 1.764728 40.229694
8.0 8.0 75.025513 -6.521385 1.480021 109.001266
8.0 4.0 56.941525 -1.491983 0.693137 196.432129
8.0 3.0 151.294037 0.810460 0.683547 165.674301
8.0 2.0 37.690765 -3.940980 2.724502 80.463211
8.0 7.0 57.811352 -4.523915 2.036335 77.992645
8.0 7.0 72.989510 -1.772883 1.197588 101.632530
8.0 2.0 3.515356 -0.441439 0.968570 177.859390
8.0 8.0 179.583740 1.871595 0.948177 189.824158
8.0 3.0 112.601036 -7.949279 0.079629 112.999680
8.0 2.0 107.366882 0.348812 0.603990 168.063217
8.0 1.0 14.225032 3.931235 0.248926 106.552979
8.0 5.0 90.811867 6.349968 2.873042 130.349182
8.0 10.0 14.751127 -8.528277 0.624238 57.860500
8.0 8.0 106.698906 2.608750 1.957584 110.829353
8.0 2.0 130.001236 -1.324991 2.091922 196.356613
8.0 12.0 27.834629 7.985704 2.887564 139.035110
8.0 10.0 162.086655 1.647442 2.905789 163.229752
8.0 12.0 83.621788 -8.550568 0.005961 129.399536
8.0 1.0 27.762323 -1.103833 1.664699 198.635269
8.0 12.0 4.634602 -4.919667 0.926310 134.876526
8.0 6.0 8.191989 8.257698 1.860283 115.298836
8.0 8.0 114.666718 8.620451 2.085782 115.021477
8.0 9.0 73.846245 -7.625037 2.858799 161.464539
8.0 4.0 33.127441 7.538258 0.936612 147.362457
8.0 9.0 51.226383 0.032928 2.900163 156.659637
8.0 7.0 178.439682 -9.784158 2.062018 198.121765
8.0 8.0 156.559647 6.224923 1.068649 168.784973
8.0 12.0 120.437439 -5.043176 0.270801 171.592422
8.0 8.0 71.493309 -0.463032 1.327465 191.590576
8.0 12.0 123.189568 -6.105417 1.160184 190.533615
8.0 5.0 38.624069 0.626485 1.010073 76.758614
8.0 2.0 24.480732 8.944241 1.784063 137.918533
8.0 6.0 87.798210 -0.806372 0.824542 143.620728
8.0 6.0 41.390095 -7.271372 1.883447 45.961639
8.0 11.0 52.978157 -4.545469 1.690749 147.838623
8.0 12.0 84.045029 8.283856 2.917364 140.610474
8.0 1.0 34.788818 -0.660127 0.355327 95.555527
8.0 12.0 152.767929 9.707571 2.168732 180.262650
8.0 7.0 51.889381 -5.694790 1.702060 66.084251
8.0 7.0 23.320990 -0.460943 1.793333 139.827118
8.0 4.0 27.739908 -4.100799 0.680897 142.640625
8.0 9.0 38.484066 9.620125 1.019218 89.828751
8.0 5.0 103.690453 -3.056522 0.798548 115.960236
8.0 10.0 42.508018 -5.036370 2.621787 127.596481
8.0 5.0 43.671085 -1.493124 0.517994 93.253105
8.0 9.0 113.914459 0.568323 2.898131 184.824341
8.0 9.0 0.052993 9.215666 2.326613 32.356567
8.0 7.0 29.946115 8.886800 1.261506 86.888184
8.0 3.0 108.554718 -7.364392 0.848893 149.582611
8.0 8.0 41.107445 -2.092142 0.075873 100.947906
8.0 10.0 57.682850 0.930798 1.583985 112.863358
8.0 1.0 34.257195 2.164788 1.098224 165.941666
8.0 12.0 19.782562 5.838943 2.869043 101.622124
8.0 6.0 142.525955 5.169804 0.641753 172.478821
8.0 5.0 137.280396 -8.680936 1.680089 182.265808
8.0 12.0 68.935539 2.306858 0.409811 136.664581
8.0 12.0 4.765196 8.351755 2.354773 65.869141
8.0 9.0 69.492264 -2.272137 1.963379 144.916718
8.0 9.0 40.794067 5.164119 0.595817 63.405968
8.0 9.0 40.452629 -3.690134 2.296350 44.191849
8.0 7.0 24.074213 1.669899 1.057234 138.389175
8.0 4.0 11.933031 7.291333 0.144660 37.361149
8.0 7.0 40.298420 -5.496592 2.095791 120.208572
8.0 12.0 6.078831 1.825183 0.331837 95.800911
8.0 2.0 52.971943 -5.231248 1.180998 130.980728
8.0 7.0 92.885918 -1.175133 0.594052 101.766998
8.0 9.0 135.917770 7.010903 1.379157 143.478165
8.0 12.0 49.909462 8.726936 2.449803 64.973816
8.0 9.0 124.631386 -9.604907 2.827746 171.965652
8.0 11.0 3.814993 -0.243003 0.967952 68.733261
8.0 2.0 157.769928 6.120197 2.334093 175.976959
8.0 7.0 37.375477 2.079745 1.890117 163.668610
8.0 8.0 44.010777 7.148112 0.608991 142.662689
8.0 6.0 86.448662 -3.687105 0.752934 149.849426
8.0 3.0 93.845444 -4.898887 0.219882 100.222305
8.0 1.0 21.413153 4.483871 0.319180 128.014618
8.0 11.0 120.110519 5.310277 0.729262 121.473969
8.0 12.0 134.357727 8.903199 1.050888 199.002655

Appendix III: SCORE binary/ASCII file parser

The following C program will read either a binary SCORE data file (which usually ends in the extension .MUS or .PAG), or an ASCII SCORE PMX file (which can be created from SCORE with the "PMX" command. See Appendix V for an example PMX file. The ASCII and binary forms of the data are essentially equivalent, although the binary form contains a header that store measurement unit information (inches or centimeters) that the ASCII version does not.

The score2pmx.c program takes either Binary or ASCII PMX data and outputs ASCII PMX data. The program can be used as the basis for loading SCORE data into a larger C program, or used as written to ensure that input data for further processing can be done on ASCII PMX data. The parser is mostly complete; EPS objects (P1=15) are not considered, but are probably handled similar to Text object (P1=16).

Compiling this program with GCC in the terminal:[10]

```
gcc -o score2pmx score2pmx.c
```

and running the program in various ways on the command-line:

```
./score2pmx input.mus > output.pmx     # binary to ASCII
./score2pmx input.pmx  > output.pmx    # ASCII to ASCII
```

The score2pmx program can accept multiple input files and will place `##PAGEBREAK` markers between each input files content in the output stream:

```
./score2pmx file1.mus file3.pmx file4.pag > allpages.pmx
```

Here is one way to to extract only staves from the input data:

```
./score2pmx file.mus | grep '^8' > staves.pmx
```

Or for multiple pages saved into on output file:

```
./score2pmx page*.mus | egrep '^[#8]' > allstaves.pmx
```

score2pmx.c

```
//
// Programmer:    Craig Stuart Sapp <craig@ccrma.stanford.edu>
// Creation Date: Wed Aug 29 13:50:35 PDT 2012
// Last Modified: Thu Aug 30 18:32:08 PDT 2012 Added ASCII PMX data reading
//                                             and a basic data structure model.
// Filename:      score2pmx.c
// Syntax:        C
//
// Description:   Convert binary or ASCII SCORE files (typically ending in the
//                extensions .mus and .pag for binary, or .pmx or .txt for
//                ASCII) into ASCII format.  There can be more than
//                one input file.  If so, then the output will contain
//                multiple pages, with each page separated by a line
```

[10] GCC is included by default in nearly all versions of Linux. To compile in Terminal.app on OS X computers, you must first install *XCode* from the Apple App store (free download). Then inside *XCode* preferences:

(1) click on Downloads tab
(2) Select command line tools
(3) click on install button (180 MB download)

After this you should have the "command line tools" setup properly for use in the unix terminal (/Applications/Utilities/Terminal.app).

```
//                starting with ##PAGEBREAK.  (Multiple page files cannot be
//                loaded into SCORE, but are useful for converting a
//                movement from SCORE into another format).
//
//                This program reads the contents of multiple SCORE files
//                (in any combination of binary or ASCII files) and stores
//                the data before printing it to standard output.  This
//                program can serve as a model for doing internal processing
//                of the SCORE data (manipulating it or converting it) before
//                output results are printed.
//
// Usage:         score2pmx file.[pmx|mus] [file2.[pmx|mus] > file.pmx
//
// Compile:       gcc -o score2pmx score2pmx.c
//

#include <string.h>
#include <stdio.h>
#include <stdlib.h>
#include <math.h>

#define BINARY_FILE 1
#define TEXT_FILE   2
#define MAX_OBJECT_COUNT 5123123

typedef struct {
   double* parameter;   // storage array for object parameters
   int     psize;       // number of parameters
   char*   text;        // text string for text objects (P1=16)
} ScoreObject;

// ScoreObject processing function declarations:
ScoreObject* createScoreObject        (int aSize);
void         changeTextField          (ScoreObject** sobjp,
                                       const char* newstring);
void         destroyScoreObject       (ScoreObject** sobjp);
void         printScoreObject         (ScoreObject* sobj);


// ScoreObject list processing function declarations:
int          addComment               (ScoreObject** slist, int objectCount,
                                       const char* comment);
void         destroyObjectList        (ScoreObject*** slistp, int objectCount);
void         printScoreObjectList     (ScoreObject** slist, int objectCount);


// function declarations:
int      getFileType                  (FILE* input);
int      readAsciiPmxFileAsAscii      (FILE* input, ScoreObject** slist,
                                       int objectCount);
int      readAsciiNumberLine          (double* param, int pcount, char* buffer);
int      readBinaryPageFileAsAscii    (FILE* input, ScoreObject** slist,
                                       int objectCount);
int      readLittleShort              (FILE* input);
double   readLittleFloat              (FILE* input);
int      readNumericObject            (double* param, int pcount, FILE* input,
                                       int count);
int      readScoreObjectFromBinaryFile(ScoreObject** sobjp, FILE* input);
int      readTextObject               (double* param, int pcount, char* string,
                                       FILE* input, int count);
char*    removeNewline                (char* buffer);
double   roundFractionDigits          (double number, int digits);
void     storeObjectParameters        (ScoreObject** sobjp, FILE* input,
```

```
                                        int count);

int debugQ   = 0;  // turn on for debugging display
int verboseQ = 0;  // turn on for seeing more info from trailer

//////////////////////////////////////////////////////////////////////////

int main(int argc, char** argv) {
   int i;
   int fileType;
   const char* filename;

   ScoreObject** slist;
   slist = (ScoreObject**)malloc(sizeof(ScoreObject*)*MAX_OBJECT_COUNT);
   int objectCount = 0;

   char buffer[1024] = {0};

   for (i=1; i<argc; i++) {
      // If there are multiple input files print an information line
      // showing the original filename for each page.
      filename = argv[i];
      if (argc > 2) {
         sprintf(buffer, "##FILE:\t%s", filename);
         objectCount = addComment(slist, objectCount, buffer);
      }

      FILE *input = fopen(filename, "r");
      if (input == NULL) {
         printf("Error: cannot open file %s for reading.\n", filename);
         exit(1);
      }

      fileType = getFileType(input);

      if (fileType == BINARY_FILE) {
         objectCount = readBinaryPageFileAsAscii(input, slist, objectCount);
      } else {
         objectCount = readAsciiPmxFileAsAscii(input, slist, objectCount);
      }

      // Print "##PAGEBREAK" after every page execept the last one
      // when there are multiple input files.
      if ((i < argc-1) && (argc > 2)) {
         objectCount = addComment(slist, objectCount, "##PAGEBREAK");
      }
   }

   // At this point the SCORE object data for (multiple) page(s) is stored
   // in the data structure called "slist".  This data can now be manipulated
   // or converted into other data formats.  In this case, just print out
   // the data which was just read in:
   printScoreObjectList(slist, objectCount);

   // Free up memory used to store the SCORE data:
   destroyObjectList(&slist, objectCount);

   return 0;
}


//////////////////////////////////////////////////////////////////////////
```

```
//////////////////////////////
//
// getFileType -- returns BINARY_FILE if the last 4 bytes of the file
//     represent the little-endinan float -9999.0; otherwise, returns
//     TEXT_FILE.  Moves the file read point back to the start of
//     the file when done.
//

int getFileType(FILE* input) {
   // A SCORE binary file must end in the hex bytes "00 3c 1c c6"
   // which represents the floating point number -9999.0.
   fseek(input, -4, SEEK_END);
   double lastNumber = readLittleFloat(input);

   // Go back to the beginning of the file:
   fseek(input, 0, SEEK_SET);

   if (lastNumber == -9999.0) {
      return BINARY_FILE;
   } else {
      return TEXT_FILE;
   }
}



//////////////////////////////
//
// readAsciiPmxFileAsAscii -- Read a text file containing PMX data for
//     musical objects (ASCII equivalent of a binary SCORE file).
//

int readAsciiPmxFileAsAscii(FILE* input, ScoreObject** slist,
      int objectCount) {
   char buffer[1024] = {0};
   double param[100] = {0};
   int pcount = 0;
   ScoreObject* sobj = NULL;
   int i;
   int len;

   while (fgets(buffer, sizeof(buffer), input)) {
      pcount = 0;
      sobj = NULL;
      if (strlen(buffer) > 1000) {
         printf("Error: text line is too long: %s\n", buffer);
         exit(1);
      } else if (strlen(buffer) < 2) {
         // empty text line: ignore it
         continue;
      }
      if (isdigit(buffer[0])) {
         // process a P1 != 16 SCORE object:
         pcount = readAsciiNumberLine(param, pcount, buffer);
         sobj = createScoreObject(pcount);
         for (i=0; i<pcount; i++) {
            sobj->parameter[i] = param[i];
         }
         sobj->psize = pcount;
         slist[objectCount++] = sobj;
         continue;
      } else if ((tolower(buffer[0]) == 't') && isspace(buffer[1])) {
```

```
         // process a text object (P1 = 16):
         buffer[0] = ' ';
         param[pcount++] = 16.0;
         pcount = readAsciiNumberLine(param, pcount, buffer);
         sobj = createScoreObject(pcount);
         for (i=0; i<pcount; i++) {
            sobj->parameter[i] = param[i];
         }
         sobj->psize = pcount;
         // the following line stores the text string:
         if (fgets(buffer, sizeof(buffer), input) == NULL) {
            printf("Error reading text object: end of file found instead\n");
            exit(1);
         }
         removeNewline(buffer);
         len = strlen(buffer);
         // string length should be the same as P12 (param[11]) but not
         // bothering to check if they match.  P12 could be 0.0, which
         // means that the length of the string is to be inferred from
         // the string itself.
         changeTextField(&sobj, buffer);
         slist[objectCount++] = sobj;
         continue;
      } else {
         // store as a text comment:
         removeNewline(buffer);
         objectCount = addComment(slist, objectCount, buffer);
      }
   }

   return objectCount;
}



////////////////////////////
//
// readAsciiNumberLine -- read a line of floating-point numbers. Returns
//    the updated pcount value.  This function is destructive on buffer.
//    The line can only contain numbers.  If there is text on the line,
//    then there might be a problem, and in any case, the data will probably
//    be junk.
//

int readAsciiNumberLine(double* param, int pcount, char* buffer) {
   char* ptr = strtok(buffer, "\n\t ");
   double number = 0.0;
   int counter = 0;

   while (ptr != NULL) {
      number = strtod(ptr, NULL);
      if (pcount > 100) {
         printf("Error: parameter count on line is too large\n");
         exit(1);
      }
      param[pcount++] = number;
      ptr = strtok(NULL, "\n\t ");
   }

   return pcount;
}
```

```
//////////////////////////////
//
// removeNewline -- remove the characters 0x0d and 0x0a at the end
//     of the string.
//

char* removeNewline(char* buffer) {
   int len = strlen(buffer);
   int i;
   for (i=len-1; i>=0; i--) {
      if ((buffer[i] == 0x0a) || (buffer[i] == 0x0d)) {
         buffer[i] = '\0';
      } else {
         return buffer;
      }
   }
   return buffer;
}



//////////////////////////////
//
// readBinaryPageFileAsAscii -- Read a binary SCORE file and store data.
//    Binary SCORE files can be read into the SCORE editor with
//    the command "G file[.mus]", ASCII parameter matric files can
//    be read into SCORE with the command "RE file.pmx".
//    The default file extension for binary files is ".mus", so it
//    is optional to specify.  Binary files may have other extensions.
//    ".pag" files are binary data files with the intention that they
//    represent a page of music rather than a system line of music.
//

int readBinaryPageFileAsAscii(FILE* input, ScoreObject** slist,
      int objectCount) {
   int countFieldByteSize = 2;
   int numberCount = -1;
   char buffer[1024] = {0};

   // First read the number of 4-byte numbers (or 4-character groupings)
   // which are found in the file after this number.  The size of this
   // number is 2 bytes for all files created with DOS versions of SCORE.
   // For Windows versions of SCORE, it is possible that this number can
   // be 4 bytes wide if the number of 4-byte values in the file exceeds
   // 0xffff.
   if (countFieldByteSize == 2) {
      numberCount = readLittleShort(input);
   }
   if (debugQ) {
      sprintf(buffer, "#number count is %d", numberCount);
      objectCount = addComment(slist, objectCount, buffer);
   }

   // Process the trailer of the file.   First verify that this is
   // a SCORE file since all SCORE binary files must end in the
   // hex bytes "00 3c 1c c6" which represents the floating point
   // number -9999.0.
   fseek(input, -4, SEEK_END);
   double lastNumber = readLittleFloat(input);
   if (debugQ) {
      sprintf(buffer, "#trailer end number is %.11f\n", lastNumber);
      objectCount = addComment(slist, objectCount, buffer);
```

```
}
if (lastNumber != -9999.0) {
   printf("Error: last number is not -9999.0: %.1lf\n", lastNumber);
   exit(1);
}

// Now read the trailer of the file.  First go to 8 bytes before the
// end of the file and read how many bytes are in the trailer
// There should be at least 5 numbers. In reverse order from the
// end of the file, these are:
//    number 1: The number of floats in the trailer (including
//              this value.  Standard value is "5.0"  For future
//              versions of SCORE, this value might be larger, but
//              it will never be smaller.  Numbers 2, 3, and 4 will
//              always have a fixed meaning in any future versions
//              of SCORE, and extra parameters will be added before
//              them in the file if this value is larger than 5.0.
//    number 2: The measurement code: 0.0 = inches, 1.0 = centimeters.
//              This is needed for certain length measurements for
//              certain objects (not often used).
//    number 3: Program version number which created the file.
//    number 4: Program serial number which created the file.
//    number 5: The last number in the trailer (i.e., the first
//              trailer byte within the file) must be set to 0.0;
//              This is an alternate way of identifying the trailer
//              after a list of objects.  No object should have a
//              parameter size of 0.0, so a parameter size of 0.0
//              would indicate the end of the data and the start
//              of the trailer.

// Read number 1 (trailer size):
fseek(input, -8, SEEK_END);
double trailerSize = readLittleFloat(input);
if (debugQ) {
   sprintf(buffer, "#trailer size is %.1lf\n", trailerSize);
   objectCount = addComment(slist, objectCount, buffer);
}
if (trailerSize < 5.0) {
   printf("Error: trailer size is too small: %.1lf\n", trailerSize);
   exit(1);
}

// Read number 2 (measurement units):
fseek(input, -12, SEEK_END);
double unitType = readLittleFloat(input);
if (debugQ) {
   sprintf(buffer, "#unit type is %.1lf\n", unitType);
   objectCount = addComment(slist, objectCount, buffer);
}
if (verboseQ) {
   if (unitType == 0.0) {
      sprintf(buffer, "##UNITS:\tinches\n");
      objectCount = addComment(slist, objectCount, buffer);
   } else if (unitType == 0.0) {
      sprintf(buffer, "##UNITS:\tcentimeters\n");
      objectCount = addComment(slist, objectCount, buffer);
   }
}

// Read number 3 (program version number):
fseek(input, -16, SEEK_END);
double versionNumber = readLittleFloat(input);
if (verboseQ) {
```

```
      sprintf(buffer, "##VERSION:\t%.2lf\n", versionNumber);
      objectCount = addComment(slist, objectCount, buffer);
   }

   // Read number 4 (program serial number):
   fseek(input, -20, SEEK_END);
   double serialNumber = readLittleFloat(input);
   if (verboseQ) {
      sprintf(buffer, "##SERIAL:\t%lf\n", serialNumber);
      objectCount = addComment(slist, objectCount, buffer);
   }

   // Now that the file trailer has been processed, return to the start
   // of the file (after the first number):
   fseek(input, countFieldByteSize, SEEK_SET);

   // start reading objects one at a time
   int readCount = 0;
   ScoreObject* sobj;
   while (!feof(input)) {
      if (numberCount - readCount - (int)trailerSize - 1 == 0) {
         // all expected numbers have been read from the file, so stop
         // reading musical objects.
         break;
      } else if (numberCount - readCount - (int)trailerSize - 1 < 0) {
         printf("Error: object data overlaps with trailer contents\n");
         exit(1);
      }

      readCount += readScoreObjectFromBinaryFile(&sobj, input);
      slist[objectCount++] = sobj;
   }


   if (fclose(input)) {
      printf("Strange error when trying to close file.\n");
      exit(1);
   }

   return objectCount;
}



//////////////////////////////
//
// readScoreObjectFromBinaryFile -- Read a SCORE object from a binary
//    file.  The return value is the number of 4-byte blocks read
//    from the file while processing the object.
//

int readScoreObjectFromBinaryFile(ScoreObject** sobjp, FILE* input) {
   int readCount = 0;
   double number;
   char buffer[1024] = {0};
   number = readLittleFloat(input);
   number = roundFractionDigits(number, 3);
   readCount++;
   if (number == 0.0) {
      printf("Error: parameter size of next object is zero.\n");
      exit(1);
   }
   readCount += (int)number;
```

```
   storeObjectParameters(sobjp, input, (int)number);
   return readCount;
}



//////////////////////////////
//
// storeObjectParameters -- print the given number of parameters
//    in the musical object at the current point in the file.
//

void storeObjectParameters(ScoreObject** sobjp, FILE* input, int count) {
   // temporary storage for ScoreObject data:
   double param[100]   = {0.0};
   int    pcount       =  0;
   char   string[1024] = {0};

   // P1 == parameter 1, which is the object type
   double P1 = readLittleFloat(input);
   param[pcount++] = P1;

   if (P1 <= 0.0) {
      printf("Strange error: P1 is non-positive: %lf\n", P1);
      exit(1);
   }
   if (P1 >= 100.0) {
      printf("Strange error: P1 is way too large: %lf\n", P1);
      exit(1);
   }
   if (P1 == 16.0) {
      // text objects use "t" instead of "16.0" for the first parameter
      // in the object when displaying as ASCII PMX data.
      pcount = readTextObject(param, pcount, string, input, count-1);
   } else {
      pcount = readNumericObject(param, pcount, input, count-1);
   }

   *sobjp = createScoreObject(pcount);
   int i;
   for (i=0; i<pcount; i++) {
      (*sobjp)->parameter[i] = param[i];
   }
   (*sobjp)->psize = pcount;
   if (param[0] == 16.0) {
      changeTextField(sobjp, string);
   }
}



//////////////////////////////
//
// readTextObject -- print a P1=16 object, starting with P2 value.
//

int readTextObject(double* param, int pcount, char* string, FILE* input,
      int count) {
   int i;
   double number;
   if (count < 12) {
      printf("Error reading binary text object: there must be 13 fixed ");
      printf("parameters, but there are instead %d.\n", count);
```

```
      exit(1);
   }

   // First read the fixed parameters for the text object:
   int characterCount = -1;
   for (i=0; i<12; i++) {
      number = readLittleFloat(input);
      number = roundFractionDigits(number, 3);
      param[pcount++] = number;
      if (i == 10) {
         // P12 is the number of characters in the string which follows.
         characterCount = (int)number;
      }
   }

   if (fread((void*)string, sizeof(char), characterCount, input) == EOF) {
      printf("Error while trying to read text string.\n");
      exit(1);
   }
   string[characterCount] = '\0';

   // Next, read extra padding bytes, since the length of the string
   // field must be a multiple of 4.  These padding bytes should be
   // spaces, but can occasionally be non-zero, so just ignore the
   // padding bytes.
   int extraBytes = characterCount % 4;
   char buffer[32] = {0};
   if ((extraBytes > 0) && (extraBytes < 4)) {
      fread((void*)buffer, sizeof(char), 4-extraBytes, input);
      buffer[4-extraBytes] = '\0';
   }

   return pcount;
}



//////////////////////////////
//
// readNumericObject -- Read a P1 != 16 object, starting with P2 value.
//    Also, PostScript objects should probably not be printed with this
//    function (but currently are).
//

int readNumericObject(double* param, int pcount, FILE* input, int count) {
   int i;
   double number;
   for (i=0; i<count; i++) {
      number = readLittleFloat(input);
      number = roundFractionDigits(number, 3);
      param[pcount++] = number;
   }
   return pcount;
}



//////////////////////////////
//
// readLittleShort -- Read a (two-byte) unsigned short at the current
//   read position in a file, and which is stored in the file in
//   little-endian ordering.
//
```

```
int readLittleShort(FILE* input) {
   unsigned char byteinfo[2];
   if (fread((void*)byteinfo, sizeof(unsigned char), 2, input) == EOF) {
      printf("Error reading little-endian float: unexpected end of file\n");
      exit(1);
   }
   int output = 0;
   output = byteinfo[1];
   output = (output << 8) | byteinfo[0];
   return output;
}



//////////////////////////////
//
// readLittleFloat -- Read a (four-byte) signed float at the
//     current position in a file, and which is stored in the file
//     in little-endian ordering.
//

double readLittleFloat(FILE* input) {
   unsigned char byteinfo[4];
   if (fread((void*)byteinfo, sizeof(unsigned char), 4, input) == EOF) {
      printf("Error reading little-endian float: unexpected end of file\n");
      exit(1);
   }
   union { float f; unsigned int i; } num;
   num.i = 0;
   num.i = byteinfo[3];
   num.i = (num.i << 8) | byteinfo[2];
   num.i = (num.i << 8) | byteinfo[1];
   num.i = (num.i << 8) | byteinfo[0];
   return num.f;
}



//////////////////////////////
//
// roundFractionDigits -- Round a floating-point number to the speicified
//    number of siginificant digits after the decimal point.  SCORE binary
//    values are floats, and they usually contain (roundoff?) junk after
//    the third digit after the decimal point.
//

double roundFractionDigits(double number, int digits) {
   double dshift = pow(10.0, (double)digits);
   if (number < 0.0) {
      return ((int)(number * dshift - 0.5))/dshift;
   } else {
      return ((int)(number * dshift + 0.5))/dshift;
   }
}


////////////////////////////////////////////////////////////////////////////
//
// ScoreObject processing functions
//
```

```
//////////////////////////////
//
// createScoreObject -- Create a ScoreObject data structure with the
//    given number of parameters (all set to default value 0.0).
//

ScoreObject* createScoreObject(int aSize) {
   if (aSize < 0) {
      printf("Error: parameter size is too small: %d\n", aSize);
      exit(1);
   }
   if (aSize > 100) {
      printf("Error: parameter size is too large: %d\n", aSize);
      exit(1);
   }
   ScoreObject* sobj = (ScoreObject*)malloc(sizeof(ScoreObject));
   sobj->psize = aSize;
   if (aSize == 0) {
      sobj->parameter = NULL;
   } else {
      sobj->parameter = (double*)malloc(sizeof(double)*aSize);
   }

   // initialize parameter list to zeros.
   int i;
   for (i=0; i<aSize; i++) {
      sobj->parameter[i] = 0.0;
   }

   // set text with empty string:
   sobj->text = (char*)malloc(sizeof(char)*1);
   sobj->text[0] = '\0';

   return sobj;
}



//////////////////////////////
//
// destroyScoreObject -- Deallocate a ScoreObject data structure.
//

void destroyScoreObject(ScoreObject** sobjp) {
   if ((*sobjp)->parameter != NULL) {
      free((*sobjp)->parameter);
      (*sobjp)->parameter = NULL;
   }
   if ((*sobjp)->text != NULL) {
      free((*sobjp)->text);
      (*sobjp)->text = NULL;
   }
   free(*sobjp);
   *sobjp = NULL;
}



//////////////////////////////
//
// changeTextField -- Replace the text field of a SCORE object with a new one.
//
```

```
void changeTextField(ScoreObject** sobjp, const char* newstring) {
   if ((*sobjp)->text != NULL) {
      free((*sobjp)->text);
   }
   int len = strlen(newstring);
   (*sobjp)->text = (char*)malloc(sizeof(char)*(len+1));
   strcpy((*sobjp)->text, newstring);
}



//////////////////////////////
//
// printScoreObject -- Print a ScoreObject in an ASCII PMX line which can
//    be read into SCORE with the "RE" command.
//

void printScoreObject(ScoreObject* sobj) {
   if (sobj == NULL) {
      return;
   }
   // deal with comments:
   if (sobj->psize < 1) {
      if (sobj->text != NULL) {
         printf("%s\n", sobj->text);
      }
      return;
   }
   if (sobj->psize > 100) {
      printf("Error: parameter list size is unexpectedly large: %d\n",
            sobj->psize);
      if (sobj->text != NULL) {
         printf("STRING = %s\n", sobj->text);
      } else {
         printf("STRING IS NULL!\n");
      }
      exit(1);
   }

   // print the first parameter:
   double P1 = sobj->parameter[0];
   if (((int)(P1)) == 16) {
      printf("t     ");
   } else {
      if (P1 < 10) {
         // The first character on the line for a PMX should not be a space.
         // The fractional value is usually not used (always .0000).  But
         // Walter's data and the newest Windows SCORE files may contain
         // non-zero fraction digits which describe the layer number of
         // the object on the staff.
         printf("%1.4lf", P1);
      } else {
         printf("%2.3lf", P1);
      }
   }

   int i;
   for (i=1; i<sobj->psize; i++) {
      printf(" %8.3lf", sobj->parameter[i]);
   }
   printf("\n");

   // print text string if P1=16:
```

```
   if (((int)(P1)) == 16) {
      if (sobj->text != NULL) {
         printf("%s\n", sobj->text);
      }
   }
}

////////////////////////////////////////////////////////////////////////
//
// ScoreObject list processing fuctions
//

//////////////////////////////
//
// addComment -- Add a text comment to the SCORE object list.  Returns
//    the new size of the list.
//

int addComment(ScoreObject** slist, int objectCount, const char* comment) {
   ScoreObject* sobj = createScoreObject(0);
   changeTextField(&sobj, comment);
   if (objectCount >= MAX_OBJECT_COUNT) {
      printf("Error: maximum object count reached.  Out of memory.\n");
      exit(1);
   }
   slist[objectCount] = sobj;
   return objectCount+1;
}



//////////////////////////////
//
// destroyObjectList -- Deallocate all ScoreObject in list, then destory
//    list.
//

void destroyObjectList(ScoreObject*** slistp, int objectCount) {
   int i;
   if ((*slistp) == NULL) {
      return;
   }
   for (i=0; i<objectCount; i++) {
      destroyScoreObject(&((*slistp)[i]));
      (*slistp)[i] = NULL;
   }
   free((*slistp));
   (*slistp) = NULL;
}



//////////////////////////////
//
// printScoreObjectList --  Print a list of ScoreObjects.
//

void printScoreObjectList(ScoreObject** slist, int objectCount) {
   int i;
   for (i=0; i<objectCount; i++) {
      printScoreObject(slist[i]);
   }
}
```

The following code is an example of how to identify system groupings of staves. The code can be added to the above program. Here is the output of the new program, using the test page of PMX data from Appendix V:

```
System 1:   697,743 4814,1389
      Staff 12:   697,743 4814,915
      Staff 11:   697,1217 4814,1389
System 2:   315,1690 4814,2334
      Staff 10:   315,1690 4814,1862
      Staff 9:    315,2162 4814,2334
System 3:   315,2635 4814,3279
      Staff 8:    315,2635 4814,2807
      Staff 7:    315,3107 4814,3279
System 4:   315,3579 4814,4224
      Staff 6:    315,3579 4814,3752
      Staff 5:    315,4052 4814,4224
System 5:   315,4525 4814,5169
      Staff 4:    315,4525 4814,4697
      Staff 3:    315,4997 4814,5169
System 6:   315,5470 4814,6114
      Staff 2:    315,5470 4814,5642
      Staff 1:    315,5942 4814,6114
```

To use the following code, comment out the printScoreObjectList function call in main(), and add printStaffPixelBoundingBoxes():

```
// printScoreObjectList(slist, objectCount);
printStaffPixelBoundingBoxes(slist, objectCount);
```

```
// functions related to pixel bounding box calculations:
void     printStaffPixelBoundingBoxes (ScoreObject** slist, int objectCount);
void     getStaffPixelBoundingBox     (ScoreObject* staffobj, int* ulx,
                                       int* uly, int* lrx, int* lry,
                                       float lmargin, float bmargin,
                                       float scale, float linewidth, int DPI,
                                       int rDPI, int oDPI);
void     getSystemPixelBoundingBox    (ScoreObject* staffobj, int* ulx,
                                       int* uly, int* lrx, int* lry,
                                       float lmargin, float bmargin,
                                       float scale, float linewidth, int DPI,
                                       int rDPI, int oDPI, int* system,
                                       int sysnum, ScoreObject** staves,
                                       int staffcount);
float    fixNearIntegers              (float value);
float    setStrokeAdjust              (float value, int sDPI, int rDPI,
                                       int oDPI, int direction);

// System identification functions:
int      isBarlineObject              (ScoreObject* sobjp);
int      isStaffObject                (ScoreObject* sobjp);
```

```
int      getStaff                     (ScoreObject* sobjp);
int      getMaxStaff                  (ScoreObject** slist, int count);
int      getObjectType                (int atype, ScoreObject** barlines,
                                       ScoreObject** slist, int count);
int      getBarHeight                 (ScoreObject* sobjp);
int      calculateSystemAssignments   (ScoreObject** slist, int count,
                                       int* system);


//////////////////////////////////////////////////////////////////////////


//////////////////////////////
//
// getParameter -- return the specified parameter number's value.
//   Return 0.0 if parameter is not in the list.  Parameter number is
//   offset from 1 rather than 0.
//

float getParameter(ScoreObject* sobjp, int param) {
   param -= 1;          // make param be 0-index
   if ((param < 0) || (param >= sobjp->psize)) {
      return 0.0;
   } else {
      return sobjp->parameter[param];
   }
}


//////////////////////////////////////////////////////////////////////////
//
// Staff localization functions
//

//////////////////////////////
//
// getStaffPixelBoundingBox --
// Parameters:
//   staffobj = SCORE PMX data for a staff
// OUTPUT values:
//   ulx = upper left corner's horizontal pixel
//   uly = upper left corner's vertical pixel
//   lrx = lower right corner's horizontal pixel
//   lry = lower right corner's vertical pixel
// INPUT Printing variables:
//   lmargin   = left margin, in inches
//   bmargin   = bottom margin, in inches
//   scale     = global music scaling factor (does not affect margins)
//   linewidth = stroke width of staff line in pixels
//   DPI       = target DPI for calculating physical width of linewidth
//   rDPI      = rendering DPI used for stroke-adjust calculations
//   oDPI      = output DPI used for matching to image's rendered DPI.
//

void getStaffPixelBoundingBox(ScoreObject* staffobj, int* ulx, int* uly,
      int* lrx, int* lry, float lmargin, float bmargin, float scale,
      float linewidth, int DPI, int rDPI, int oDPI) {
```

```
// clear any old contents of bounding box
*ulx = *uly = *lrx = *lry = -1;

int P1 = (int)getParameter(staffobj, 1);
if (P1 != 8) {
   // score object is not a staff, so ignore it
   return;
}

int    P2 = (int)getParameter(staffobj, 2);
double P3 = getParameter(staffobj, 3);
double P4 = getParameter(staffobj, 4);
double P5 = getParameter(staffobj, 5);
double P6 = getParameter(staffobj, 6);

if (P5 <= 0.0) {
   P5 = 1.0;               // default vertical staff scaling
}
if (P6 <= 0.0) {
   P6 = 200.0;             // default right position of staff
}

float PAGEHEIGHT = 11.0;    // hard-wired to letter-sized paper for now
float LM = lmargin * 72.0;  // left margin in points
float BM = bmargin * 72.0;  // left margin in points
if (linewidth <= 0.0) {
   linewidth = 1.0;
}
float linewidthsmall = linewidth - 1;
if (linewidthsmall <= 0.0) {
   linewidthsmall = 1;
}
float strokeBig   = linewidth / DPI * oDPI;
float strokeSmall = linewidthsmall / DPI * oDPI;

// constants (in points):
float Lx   = 0.025   * 72.0;   // left margin buffer
float Bx   = 0.0625  * 72.0;   // bottom margin buffer
float Len  = 7.5     * 72.0;   // default full length of staff
float Step = 0.04375 * 72.0;   // vertical diatonic step size
float Vx   = 0.7875  * 72.0;   // default spacing of successive staves
int   sDPI = 4000;             // SCORE's printing DPI

float dpi72to4000 = sDPI/72.0; // conversion from points to 4000 DPI
float hoffset4000 = (LM + Lx) * dpi72to4000;          // default is 2100
float voffset4000 = (BM + Bx + 6 * 72) * dpi72to4000; // default is 27250

float LW = strokeBig;
if (P5 < 0.65) {
   LW = strokeSmall;
}

// width of the staff (in points):
float width   = scale * (Len*(P6-P3)/200.0);

// left-hand horizontal position of the staff on page (in points):
```

```
   float hlpos   = LM + Lx + scale * (Len*P3/200.0);

   // vertical position of bottom line of staff on page (to center of line):
   float vbottom = BM + Bx + scale * ((P2-1)*Vx + P4*P5*Step);


   // vertical distance between staff lines (in points);
   float lspace  = Step * 2 * P5 * scale;

   // scale to 4000-DPI coordinates (from 72-DPI coordinates):
   hlpos   *= dpi72to4000;
   vbottom *= dpi72to4000;
   width   *= dpi72to4000;
   lspace  *= dpi72to4000;

   int linecount = 5;    // could be read from SCORE staff object parameters
   float diatonicstep = 175 * P5;
   float vorigin = vbottom - 3.0 * diatonicstep;;

   // 4000-DPI quantized versions of variables:
   float hlposq   = hlpos;
   float widthq   = width;
   float hrposq;

   hlposq   = (int)fixNearIntegers(hlposq);
   widthq   = (int)widthq;
   hrposq   = width + hlpos;
   hrposq   = (int)fixNearIntegers(hrposq);


   float vpos_bottom = vorigin + 3 * diatonicstep;
   float vpos_top    = vorigin + (3+(linecount-1)*2) * diatonicstep;


   float vposq_bottom = (int)fixNearIntegers(vpos_bottom);
   float vposq_top    = (int)fixNearIntegers(vpos_top);

   // apply stroke-adjustment and convert to oDPI:
   hlposq       = setStrokeAdjust(hlposq,       sDPI, rDPI, oDPI, +1);
   hrposq       = setStrokeAdjust(hrposq,       sDPI, rDPI, oDPI, -1);
   vposq_bottom = setStrokeAdjust(vposq_bottom, sDPI, rDPI, oDPI, -1);
   vposq_top    = setStrokeAdjust(vposq_top,    sDPI, rDPI, oDPI, -1);

   // flip vertical origin from bottom left corner to top left corner:
   vposq_bottom = PAGEHEIGHT * oDPI - vposq_bottom;
   vposq_top    = PAGEHEIGHT * oDPI - vposq_top;

   // Do the final calculations of the pixel bounding box for the staff.
   // The horizontal positions (ulx, lrx) are already calculated.
   // The top y value is vpos of top line minus 1/2 of stroke width.
   // The bottom y value is vpos of top line plus 1/2 of stroke width.
   *ulx = (int)hlposq;
   *lrx = (int)hrposq;
   *uly = (int)(vposq_top - LW/2.0);
   *lry = (int)(vposq_bottom + LW/2.0);
}
```

```
//////////////////////////////
//
// fixNearIntegers -- force a snap to integer value if float value
//   is very close to an integer.  Fixes case where float value moves
//   by nearly 1.0 when converting to integers.
//

float fixNearIntegers(float value) {
   if (value < 0.0) {
      return value - 0.0001;
   }
   if (value > 0.0) {
      return value + 0.0001;
   }
   return value;
}



//////////////////////////////
//
// setStrokeAdjust -- Quantize position to quarter-pixel offset in rendering
//   DPI.
//

float setStrokeAdjust(float value, int sDPI, int rDPI, int oDPI,
      int direction) {
   float devicepos = direction * value / sDPI * rDPI;
   devicepos = floor(devicepos) + 0.25;
   float newvalue = direction * devicepos / rDPI * oDPI;
   if (fabs(newvalue - ((int)newvalue) - 0.75) < 0.0001) {
      newvalue -= 0.50;
   }
   return newvalue;
}



//////////////////////////////
//
// getSystemPixelBoundingBox -- returns the bounding-box for a system.
//     see getStaffPixelBoundingBox() for meaning of input variables.
// Other input variables not part of getStaffPixelBoundingBox():
//    system == staff to system mapping
//    sysnum == target system number (counting from 1 starting at top of page)
//    staves == lists of P1=8 (staves) on the page
//    staffcount == number of objects in staves list.
//

void getSystemPixelBoundingBox(ScoreObject* staffobj, int* ulx, int* uly,
      int* lrx, int* lry, float lmargin, float bmargin, float scale,
      float linewidth, int DPI, int rDPI, int oDPI, int* system, int sysnum,
      ScoreObject** staves, int staffcount) {
   *ulx = *uly = *lrx = *lry = -1;
   int topstaff    = -1;
```

```
   int bottomstaff = -1;
   int i, j;
   for (i=1; i<100; i++) {
      if (system[i] <= 0) {
         continue;
      }
      if (system[i] == sysnum) {
         if (bottomstaff < 0) {
            bottomstaff = i;
         }
         topstaff = i;
      }
   }

   ScoreObject* tstaff = NULL;
   ScoreObject* bstaff = NULL;

   for (j=0; j<staffcount; j++) {
      if (topstaff == getStaff(staves[j])) {
         tstaff = staves[j];
      }
      if (bottomstaff == getStaff(staves[j])) {
         bstaff = staves[j];
      }
   }

   int ulxt, ulyt, lrxt, lryt;
   int ulxb, ulyb, lrxb, lryb;

   getStaffPixelBoundingBox(tstaff, &ulxt, &ulyt, &lrxt, &lryt, lmargin,
           bmargin, scale, linewidth, DPI, rDPI, oDPI);

   getStaffPixelBoundingBox(bstaff, &ulxb, &ulyb, &lrxb, &lryb, lmargin,
           bmargin, scale, linewidth, DPI, rDPI, oDPI);

  // presuming that all staves in the system have the same horizontal
  // endpoints.
  *ulx = ulxt;
  *lrx = lrxt;

  // top left vertical position of top staff is top left corner of system:
  *uly = ulyt;

  // bottom right position of bottom staff is bottom right corner of system:
  *lry = lryb;

}


//////////////////////////////////////////////////////////////////////////
//
// System idenfication functions
//

////////////////////////////
//
// printStaffPixelBoundingBoxes -- print the pixel bounding boxes for each
```

```
//   staff in the data list.
//

void printStaffPixelBoundingBoxes(ScoreObject** slist, int objectCount) {
   int i, j;
   int P1;
   int ulx, uly, lrx, lry;

   int system[100];
   int syscount = calculateSystemAssignments(slist, objectCount, system);
   ScoreObject* staves[objectCount];
   int staffcount = getObjectType(8, staves, slist, objectCount);

   // default print settings:
   float lmargin   = 0.50;
   float bmargin   = 0.75;
   float scale     = 1.00;
   float linewidth = 4.0;
   int   DPI       = 600;
   int   rDPI      = 600;
   int   oDPI      = 600;

   ScoreObject* tstaff;
   int lastsystem = -1;
   for (i=99; i>0; i--) {
      if (system[i] <= 0) {
         continue;
      }
      if (system[i] != lastsystem) {
         getSystemPixelBoundingBox(slist[i], &ulx, &uly, &lrx, &lry, lmargin,
            bmargin, scale, linewidth, DPI, rDPI, oDPI, system, system[i],
            staves, staffcount);
         printf("System %d:\t%d,%d %d,%d\n", system[i], ulx, uly, lrx, lry);
         lastsystem = system[i];
      }
      tstaff = NULL;
      for (j=0; j<staffcount; j++) {
         if (i == getStaff(staves[j])) {
            tstaff = staves[j];
            break;
         }
      }
      if (tstaff == NULL) {
         continue;
      }
      getStaffPixelBoundingBox(tstaff, &ulx, &uly, &lrx, &lry, lmargin,
           bmargin, scale, linewidth, DPI, rDPI, oDPI);
      printf("\tStaff %d:\t%d,%d %d,%d\n", i, ulx, uly, lrx, lry);
   }
}



////////////////////////////
//
// calculateSystemAssignments -- group staves into systems.  Examine how each
//    staff is connected to others, and systems are defined where there are
```

```
//    gaps between staves with no barlines.  Returns the number of systems
//    on the page.  If there are no barlines on a staff, then this system
//    extraction algorithm will not work (staff will be ignored).
//

int calculateSystemAssignments(ScoreObject** slist, int count, int* system) {
   int i, j, k;
   for (i=0; i<100; i++) {
      system[i] = -1;
   }
   int maxstaff = getMaxStaff(slist, count);
   int P2;
   int barheight;
   int target;
   ScoreObject* barlines[count];
   int barcount = getObjectType(14, barlines, slist, count);
   for (i=1; i<maxstaff; i++) {
      for (j=0; j<barcount; j++) {
         P2 = getStaff(barlines[j]);
         if (P2 != i) {
            continue;
         }
         barheight = getBarHeight(barlines[j]);
         for (k=0; k<barheight; k++) {
            target = i;
            if (system[P2+k] == -1) {
               system[P2+k] = target;
            } else {
               target = system[P2+k];
            }
         }
      }
   }

   // system array contains a list of systems marked by the lowest
   // staff in the system.  Renumber the systems so that the top
   // system on the page is system 1, then increment by 1 going down
   // the page.

   int currentSystem = 0;
   int laststaff = -1;
   for (i=98; i>0; i--) {
      if (system[i] <= 0) {
         continue;
      }
      if (system[i] == laststaff) {
         system[i] = currentSystem;
      } else {
         laststaff = system[i];
         system[i] = ++currentSystem;
      }
   }

   return currentSystem;
}
```

```
//////////////////////////////
//
// getBarHeight -- returns the number of staves that the barline attaches
//     to.
//

int getBarHeight(ScoreObject* sobjp) {
   int P4 = abs((int)getParameter(sobjp, 4));
   if (P4 == 0) {
      P4 = 1;
   }
   P4 = P4 % 100;
   return P4;
}



//////////////////////////////
//
// getBarlines -- create a list of all objects of a particular type.
//    returns the number of objects which were found in the input list.
//

int getObjectType(int atype, ScoreObject** list, ScoreObject** slist,
      int count) {
   int i;
   int tcount = 0;
   int P1;
   for (i=0; i<count; i++) {
      P1 = (int)getParameter(slist[i], 1);
      if (P1 != atype) {
         continue;
      }
      list[tcount++] = slist[i];
   }
   return tcount;
}



//////////////////////////////
//
// getMaxStaff -- returns the highest staff number given in all
//    staff objects on page.
//

int getMaxStaff(ScoreObject** slist, int count) {
   int i;
   int output = 0;
   int P2;
   for (i=0; i<count; i++) {
      if (!isStaffObject(slist[i])) {
         continue;
      }
      P2 = getStaff(slist[i]);
      if (output < P2) {
```

```
            output = P2;
         }
      }
      if (output > 98) {
         output = 98;
      }
      return output;
}



//////////////////////////////
//
// getStaff -- returns the staff number to which the object belongs.
//

int getStaff(ScoreObject* sobjp) {
   return (int)getParameter(sobjp, 2);
}



//////////////////////////////
//
// isStaffObject -- returns true if P1=8.
//

int isStaffObject(ScoreObject* sobjp) {
   int P1 = (int)getParameter(sobjp, 1);
   return P1 == 8 ? 1 : 0;
}



//////////////////////////////
//
// isBarlineObject -- returns true if P1=14.
//

int isBarlineObject(ScoreObject* sobjp) {
   int P1 = (int)getParameter(sobjp, 1);
   return P1 == 14 ? 1 : 0;
}
```

Appendix IV: Pretty-printer for SCORE PMX data

SCORE's ASCII PMX data consists of lines of numbers, each separated by one or more space (but not tabs). The following PERL script, *prettypmx*, can be used to vertically align parameter values across multiple lines. This makes it easier to read through parameters, but does not affect how the file is read into SCORE.

Here is sample output direct from the SCORE PMX command. Most data is aligned vertically, but not in all cases. And the width of the data is wider than required to align the parameters. This causes some lines (P1=6 for beams) to be wrapped onto a second line.

```
8.  1.0    .000      .00      .90    80.00
14.  1.0    .000     2.00     8.00
14.  1.0    .000     2.00
3.  1.0   1.238
18.  1.0   7.426      .00    99.00     1.00
1.  1.0  13.614     1.00    10.00      .00      .5000     3.50
6.  1.0  13.614     4.50     4.50    24.08    11.0000
1.  1.0  17.102     5.00    10.00      .00      .5000     -.50
1.  1.0  20.590     3.00    10.00      .00      .5000     1.50
1.  1.0  24.079     5.00    10.00      .00      .5000     -.50
1.  1.0  27.567     1.00    10.00      .00      .5000     3.50
6.  1.0  27.567     4.50     4.50    38.03    11.0000
1.  1.0  31.055     5.00    10.00      .00      .5000     -.50
1.  1.0  34.543     3.00    10.00      .00      .5000     1.50
1.  1.0  38.031     5.00    10.00      .00      .5000     -.50
14.  1.0  43.769     2.00
1.  1.0  45.457     2.00    10.00      .00      .5000     2.50
6.  1.0  45.457     4.50     4.50    55.92    11.0000      .00       .00       .00\
      .00       .00       .00       .00      1.50
1.  1.0  48.945     5.00    10.00      .00      .5000     -.50       .00       .38
1.  1.0  52.433     4.00    10.00      .00      .5000      .50       .00       .75
1.  1.0  55.921     5.00    10.00      .00      .5000     -.50       .00      1.50
1.  1.0  63.798     1.00    10.00      .00      .5000     3.50       .00      -.25
6.  1.0  63.798     4.50     4.50    74.26    11.0000      .00       .00       .00\
      .00       .00       .00      -.25
1.  1.0  67.286     5.00    10.00      .00      .5000     -.50
1.  1.0  70.774     3.00    10.00      .00      .5000     1.50
1.  1.0  74.262     5.00    10.00      .00      .5000     -.50
14.  1.0  80.000     2.00
8.  2.0    .000    -3.00      .90    80.00
3.  2.0   1.238
18.  2.0   7.426      .00    99.00     1.00
9.  2.0  13.614    -2.50    53.00     1.00
1.  2.0  13.614     8.00    20.00     1.00     2.0000
5.  2.0  14.113     9.88    12.00    26.57     1.4937    -1.00
1.  2.0  27.567    10.00    20.00      .00     1.0000
1.  2.0  34.543    12.00    20.00      .00     1.0000
1.  2.0  45.457     7.00    20.00      .00     1.5000      .00     10.00
5.  2.0  45.457    10.00    10.00    63.80     1.6687    -1.00       .00       .55
6.  2.0  55.921     7.50     8.00    60.31    22.0000      .00       .00       .00\
      .00       .00       .00      1.00
1.  2.0  55.921     8.00    20.00      .00      .2500      .50       .00      1.00
1.  2.0  60.309     9.00    20.00      .00      .2500     1.00
1.  2.0  63.798     8.00    20.00      .00     1.0000
2.  2.0  70.774      .00      .00      .00     1.0000
```

Here is output from the *prettypmx* program using the above data. The output now aligns all parameters across all objects and compacts the widths of the lines:

```
8  1  0.000  0.00  0.9 80.00
14 1  0.000  2.00  8.0
14 1  0.000  2.00
3  1  1.238
18 1  7.426  0.00 99.0  1.00
1  1 13.614  1.00 10.0  0.00  0.5000  3.5
6  1 13.614  4.50  4.5 24.08 11.0000
1  1 17.102  5.00 10.0  0.00  0.5000 -0.5
1  1 20.590  3.00 10.0  0.00  0.5000  1.5
1  1 24.079  5.00 10.0  0.00  0.5000 -0.5
1  1 27.567  1.00 10.0  0.00  0.5000  3.5
6  1 27.567  4.50  4.5 38.03 11.0000
1  1 31.055  5.00 10.0  0.00  0.5000 -0.5
1  1 34.543  3.00 10.0  0.00  0.5000  1.5
1  1 38.031  5.00 10.0  0.00  0.5000 -0.5
14 1 43.769  2.00
1  1 45.457  2.00 10.0  0.00  0.5000  2.5
6  1 45.457  4.50  4.5 55.92 11.0000  0.0  0  0.00 0 0 0  0.00 1.5
1  1 48.945  5.00 10.0  0.00  0.5000 -0.5  0  0.38
1  1 52.433  4.00 10.0  0.00  0.5000  0.5  0  0.75
1  1 55.921  5.00 10.0  0.00  0.5000 -0.5  0  1.50
1  1 63.798  1.00 10.0  0.00  0.5000  3.5  0 -0.25
6  1 63.798  4.50  4.5 74.26 11.0000  0.0  0  0.00 0 0 0 -0.25
1  1 67.286  5.00 10.0  0.00  0.5000 -0.5
1  1 70.774  3.00 10.0  0.00  0.5000  1.5
1  1 74.262  5.00 10.0  0.00  0.5000 -0.5
14 1 80.000  2.00
8  2  0.000 -3.00  0.9 80.00
3  2  1.238
18 2  7.426  0.00 99.0  1.00
9  2 13.614 -2.50 53.0  1.00
1  2 13.614  8.00 20.0  1.00  2.0000
5  2 14.113  9.88 12.0 26.57  1.4937 -1.0
1  2 27.567 10.00 20.0  0.00  1.0000
1  2 34.543 12.00 20.0  0.00  1.0000
1  2 45.457  7.00 20.0  0.00  1.5000  0.0 10
5  2 45.457 10.00 10.0 63.80  1.6687 -1.0  0  0.55
6  2 55.921  7.50  8.0 60.31 22.0000  0.0  0  0.00 0 0 0  1.00
1  2 55.921  8.00 20.0  0.00  0.2500  0.5  0  1.00
1  2 60.309  9.00 20.0  0.00  0.2500  1.0
1  2 63.798  8.00 20.0  0.00  1.0000
2  2 70.774  0.00  0.0  0.00  1.0000
```

Example uses of the *prettypmx* program on the command-line:

```
./prettypmxpl input.pmx > output.pmx
cat input.pmx | ./prettypmx.pl > output.pmx
./score2pmx input.mus | ./prettypmx.pl > output.pmx
```

prettypmx.pl

```
#!/usr/bin/perl
#
# Programmer:    Craig Stuart Sapp <craig@ccrma.stanford.edu>
# Creation Date: Sat Feb 25 09:10:04 PST 2012
# Last Modified: Sat Feb 25 09:10:04 PST 2012
# Filename:      prettypmx
# Syntax:        perl 5
#
# Description:
#

use strict;

my $COLUMNSPACE = " ";

my @contents = <>;

@contents = cleanContents(@contents);

my $i;
my $j;
my $textnext;
my @data;
my $line;
for ($i=0; $i<@contents; $i++) {
   $line = $contents[$i];
   chomp $line;
   @data = split(/\t/, $line);
   if ($line =~ /^\s*t/i) {
      $textnext = 1;
   } else {
      $textnext = 0;
   }
   for ($j=0; $j<@data; $j++) {
      print $data[$j];
      if ($j <@data-1) {
         print $COLUMNSPACE;
      }
   }
   print "\n";

   if ($textnext) {
      chomp $contents[$i+1];
      print "$contents[$i+1]\n";
      $i++;
   }
}

//////////////////////////////////////////////////////////////////////////////

//////////////////////////////
//
// cleanContents --
//

sub cleanContents {
   my @input = @_;
   my @output;

   my $i;
```

```
my $j;
my $textnext;
my $line;
my @data;
my $value;
my $lout;
my @fracdig;

for ($i=0; $i<@input; $i++) {
   $line = $input[$i];
   chomp $line;
   if ($line =~ /^\s*t\s/i) {
      $textnext = 1;
   } else {
      $textnext = 0;
      if ($line !~ /^\s*\d/) {
         $line =~ s/\s+$//;
         $input[$i] = $line;
         next;
      }
   }
   $line =~ s/^\s+//;
   $line =~ s/\s+$//;
   @data = split(/\s+/, $line);
   $lout = "";
   for ($j=0; $j<@data; $j++) {
      $value = $data[$j];
      if ($value =~ /t/i) {
         $lout .= "\t$value";
      } else  {
         if ($value =~ /^\./) {
            $value = "0$value";
         } elsif ($value =~ /^-\./) {
            $value =~ s/^-\.//;
            $value = "-0.$value";
         }
         if ($value =~ /\./) {
            # remove trailing zeros after decimal point
            $value =~ s/0+$//;
         }
         $lout .= "\t$value";
         $fracdig[$j] = getMaxFractionalDigits($value, $fracdig[$j]);
      }
   }
   $lout =~ s/^\s+//;
   $input[$i] = $lout;
   if ($textnext) {
      $input[$i+1] =~ s/[\r\n]+$//;
      $i++;
   }
}

# remove trailing zeros but keep at least the first four values
for ($i=0; $i<@input; $i++) {
   $line = $input[$i];
   chomp $line;
   if ($line =~ /^\s*t/i) {
      $textnext = 1;
   } else {
      $textnext = 0;
      if ($line !~ /^\s*\d/) {
         next;
      }
```

```
    }
    $line =~ s/^\s+//;
    $line =~ s/\s+$//;
    @data = split(/\s+/, $line);
    for ($j=$#data; $j>=4; $j--) {
       if ($data[$j] == 0) {
          pop(@data);
       } else {
          last;
       }
    }
    $lout = "";
    for ($j=0; $j<@data; $j++) {
       $lout .= "\t$data[$j]";
    }
    $lout =~ s/^\t//;
    $input[$i] = $lout;
    $i++ if $textnext;
}

# add trailing zeros if needed to match fracdig for each column

my $tval;
my $digits;
my $add;
my $k;
for ($i=0; $i<@input; $i++) {
    $line = $input[$i];
    if ($line =~ /^\s*t/i) {
       $textnext = 1;
    } else {
       $textnext = 0;
       if ($line !~ /^\s*\d/) {
          next;
       }
    }
    $line =~ s/^\s+//;
    $line =~ s/\s+$//;
    @data = split(/\s+/, $line);
    $lout = "";
    for ($j=0; $j<@data; $j++) {
       $value = $data[$j];
       if ($value =~ /t/i) {
          $lout .= "\t$value";
       } else {
          if ($fracdig[$j] == 0) {
             $value =~ s/\.$//;
             $lout .= "\t$value";
             next;
          }

          $value =~ /\.(\d*)$/;
          $tval = $1;
          $digits = length($tval);
          $add = $fracdig[$j] - $digits;
          if (($add > 0) && ($value !~ /\./)) {
             $value .= ".";
          }
          for ($k=0; $k<$add; $k++) {
             $value .= "0";
          }
          $lout .= "\t$value";
       }
```

```
    }
    $lout =~ s/^\s+//;
    $input[$i] = $lout;
    $i++ if $textnext;
}

# count left-hand characters max for each column

my @ldigits;
for ($i=0; $i<@input; $i++) {
    $line = $input[$i];
    if ($line =~ /^\s*t/i) {
        $textnext = 1;
    } else {
        $textnext = 0;
        if ($line !~ /^\s*\d/) {
            next;
        }
    }
    $line =~ s/^\s+//;
    $line =~ s/\s+$//;
    @data = split(/\s+/, $line);
    $lout = "";
    for ($j=0; $j<@data; $j++) {
        $value = $data[$j];
        $value =~ /^([-\d]+)\.?$/;
        $tval = $value;
        $tval =~ s/\..*//;
        die "value = $value, before decimal: $tval" if $tval =~ /^\s*$/;
        $digits = length($tval);
        $ldigits[$j] = 0 if $ldigits[$j] =~ /^\s*$/;

        $ldigits[$j] = $digits if $digits > $ldigits[$j];

        $lout .= "\t$value";
    }
    $lout =~ s/^\s+//;
    $input[$i] = $lout;
    $i++ if $textnext;
}

# Add spaces before values to match column lenghts before decimal.

for ($i=0; $i<@input; $i++) {
    $line = $input[$i];
    if ($line =~ /^\s*t/i) {
        $textnext = 1;
    } else {
        $textnext = 0;
        if ($line !~ /^\s*\d/) {
            next;
        }
    }
    $line =~ s/^\s+//;
    $line =~ s/\s+$//;
    @data = split(/\s+/, $line);
    $lout = "";
    for ($j=0; $j<@data; $j++) {
        $value = $data[$j];
        $value =~ /([-\d]+)\.?$/;
        $tval = $value;
        $tval =~ s/\..*//;
        $digits = length($tval);
```

```
         $add = $ldigits[$j] - $digits;
         for ($k=0; $k<$add; $k++) {
            if ($j == 0) {
               $value .= " ";
            } else {
               $value = " $value";
            }
         }
         $lout .= "\t$value";
      }
      $lout =~ s/^\t+//;
      $input[$i] = $lout;
      $i++ if $textnext;
   }

   return @input;
}

##############################
##
## getMaxFractionalDigits --
##

sub getMaxFractionalDigits {
   my ($value, $fracdig) = @_;
   $fracdig = 0 if $fracdig =~ /^\s*$/;

   my $digits = 0;

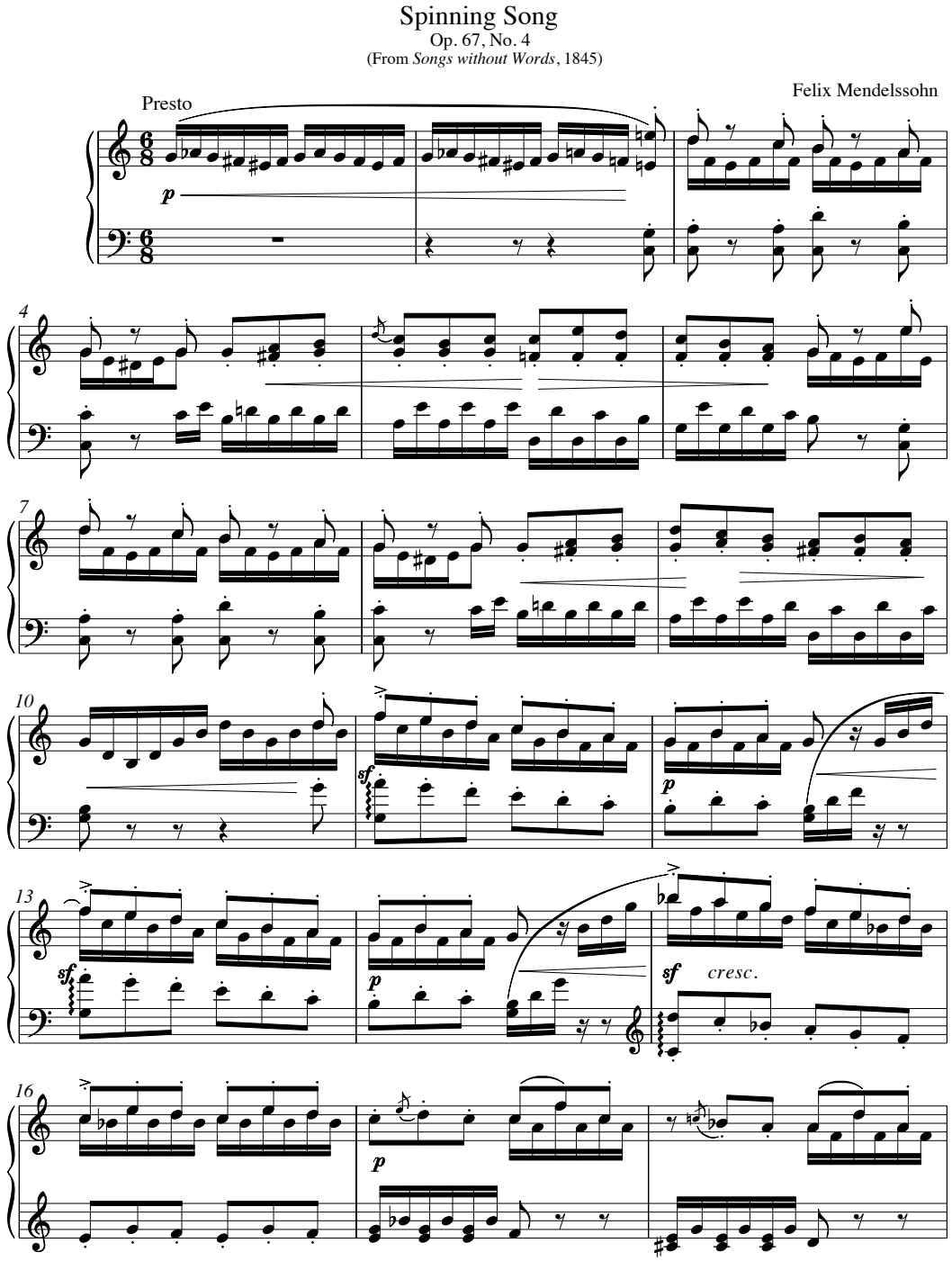
   if ($value !~ /\./) {
      # no fractional digits
      return $fracdig;
   }

   $value =~ s/.*\.//;
   $digits = length($value);

   if ($digits > $fracdig) {
      return $digits;
   } else {
      return $fracdig;
   }
}
```

Appendix V: Spinning Song PMX data

The following SCORE PMX data describes the first page of Spinning Song by Felix Mendelssohn which is used as the example music in Figure 14 on page 47. Here is the graphical music notation that the following PMX data will generate:



```
8   1   0.000   0.000   0.80 200.000
14  1   0.000   2.000
14  1   0.000   2.000   8.00
3   1   2.025
1   1  13.095   3.000  10.00   0.000  0.5000   1.50  0.00  0.00  7.000
6   1  13.095   4.500   4.50  32.810 11.0000
1   1  23.304   5.000  10.00   0.000  0.5000  -0.50  0.00  0.00  7.000
1   1  32.805   4.000  10.00   0.000  0.5000   0.50  0.00  0.00  7.000
1   1  42.700   3.000  10.00   0.000  0.5000   1.50  0.00  0.00  7.000
6   1  42.700   4.500   4.50  62.090 11.0000
1   1  52.595   5.000  10.00   0.000  0.5000  -0.50  0.00  0.00  7.000
1   1  62.096   4.000  10.00   0.000  0.5000   0.50  0.00  0.00  7.000
14  1  72.679   2.000
1   1  75.514   3.000  10.00   0.000  0.2500   5.00
1   1  75.514   5.000   0.00   0.000  0.2500
6   1  75.514   8.000   8.00 100.790 12.0000
1   1  81.924   7.000  11.00   0.000  0.2500   1.00
1   1  86.256   3.000  10.00   0.000  0.2500   5.00
1   1  86.256   5.000   0.00   0.000  0.2500
1   1  91.185   7.000  10.00   0.000  0.2500   1.00
1   1  95.738   3.000  10.00   0.000  0.2500   5.00
1   1  95.738   5.000   0.00   0.000  0.2500
1   1 100.792   7.000  10.00   0.000  0.2500   1.00
1   1 105.720   4.000  10.00   0.000  0.5000   0.50  1.00
2   1 115.615   0.000   1.00   0.000  0.5000
2   1 125.078   0.000   1.00   0.000  0.5000
14  1 135.662   2.000
1   1 139.612   1.000  12.02   0.000  0.2500   4.50
1   1 139.612   3.000   0.00   0.000  0.2500
6   1 139.612   5.500   5.50 165.130 12.0000
1   1 144.978   5.000  10.00   0.000  0.2500   0.50
1   1 150.344   1.000  10.00   0.000  0.2500   4.50
1   1 150.344   3.000   0.00   0.000  0.2500
1   1 155.273   5.000  10.00   0.000  0.2500   0.50
1   1 160.201   1.000  10.00   0.000  0.2500   4.50
1   1 160.201   3.000   0.00   0.000  0.2500
1   1 165.130   5.000  10.00   0.000  0.2500   0.50
1   1 170.058   2.000  10.00   0.000  0.5000   0.50  1.00
2   1 179.953   0.000   1.00   0.000  0.5000
2   1 189.416   0.000   1.00   0.000  0.5000
14  1 200.000   2.000
8   2   0.000   0.000   0.80 200.000
3   2   2.025
1   2  13.095   8.000  20.00   0.000  0.2500   1.50  0.00  0.00  0.000  0.00 0.50  7.75
1   2  13.095   8.000  10.00   0.000  0.5000   0.50  0.00  0.00 -9.000  0.00 0.00 -2.00  0.0 0 0 0.90
6   2  13.095   8.500   8.50  32.810 11.0000
6   2  13.095   6.500   6.50  37.750 22.0000
1   2  18.857   7.000  21.93   0.000  0.2500   0.50
1   2  23.304  10.000  10.00   0.000  0.5000  -1.50  0.00  0.00  7.000  0.00 1.00  8.50
1   2  23.304  10.000  20.00   0.000  0.2500   3.50
1   2  27.857   7.000  20.00   0.000  0.2500   0.50
1   2  32.805   9.000  10.00   0.000  0.5000  -0.50  0.00  0.00  7.000  0.00 1.00 10.50
1   2  32.805   9.000  20.00   0.000  0.2500   2.50
1   2  37.752   7.000  20.00   0.000  0.2500   0.50
1   2  42.700   8.000  10.00   0.000  0.5000   0.50  0.00  0.00  7.000  0.00 1.00 10.50
1   2  42.700   8.000  20.00   0.000  0.2500   1.50
6   2  42.700   6.500   6.50  67.040 22.0000
6   2  42.700   8.500   8.50  62.090 11.0000
1   2  47.647   7.000  20.00   0.000  0.2500   0.50
1   2  52.595  10.000  10.00   0.000  0.5000  -1.50  0.00  0.00  7.000  0.00 1.00  8.50
1   2  52.595  10.000  20.00   0.000  0.2500   3.50
1   2  57.148   7.000  20.00   0.000  0.2500   0.50
1   2  62.096   9.000  20.00   0.000  0.2500   2.50  0.00  0.00  0.000  0.00 0.00  0.50
1   2  62.096   9.000  10.00   0.000  0.5000  -0.50  0.00  0.00  7.000  0.00 1.00 10.50
1   2  67.043   7.000  20.00   0.000  0.2500   0.50
1   2  75.514   8.000  20.00   0.000  0.5000  -1.00  0.00  0.00  7.000
6   2  75.514   9.000   9.00  95.860 21.0000
9   2  76.356  -2.950  53.00
1   2  81.308 110.000  10.00   0.000 65.0000 100.00  1.00
5   2  82.085   8.530   8.09  85.130 -0.7900   0.00 -0.25  0.40  0.000  0.00 0.50
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1   2  86.006   9.000  20.00   0.000  0.5000   0.00  0.00  0.00  7.000
1   2  95.863   8.000  20.00   0.000  0.5000  -1.00  0.00  0.00  7.000
6   2 105.720   5.500   5.50 130.030 22.0000
1   2 105.720   8.000  10.00   0.000  0.5000   0.50
6   2 105.720   8.500   8.50 125.070 11.0000
1   2 105.720   8.000  20.00   0.000  0.2500   2.50
5   2 105.720  16.150  16.15 115.610  1.4035  -4.00
1   2 110.668   6.000  20.00   0.000  0.2500   0.50
1   2 115.615  11.000  20.00   0.000  0.2500   5.50
1   2 115.615  11.000  10.00   0.000  0.5000  -2.50
1   2 120.131   6.000  20.00   0.000  0.2500   0.50
1   2 125.078   8.000  20.00   0.000  0.2500   2.50
1   2 125.078   8.000  10.00   0.000  0.5000   0.50  0.00  0.00  7.000  0.00 1.00 10.50
1   2 130.026   6.000  20.00   0.000  0.2500   0.50
2   2 139.612   0.000   1.00   0.000  0.5000
1   2 145.646 108.000  13.00   0.000 65.0000 100.00  1.00 -0.50
5   2 146.203   6.380   3.88 150.760 -1.0000   0.00  0.00  0.00  0.000  0.00 0.50
6   2 150.344   6.500   6.00 160.200 11.0000
1   2 150.344   7.000  11.95   0.000  0.5000  -0.50  0.00  0.00  7.000
1   2 160.201   6.000  10.00   0.000  0.5000   0.00  0.00  0.00  7.000
6   2 170.058   4.500   4.50 194.360 22.0000
1   2 170.058   6.000  10.00   0.000  0.5000   1.50
1   2 170.058   6.000  20.00   0.000  0.2500   1.50
6   2 170.058   7.500   7.50 189.420 11.0000
5   2 170.058  15.000  15.00 179.950  1.4223  -4.00
1   2 175.006   4.000  20.00   0.000  0.2500  -0.50
1   2 179.953   9.000  20.00   0.000  0.2500   4.50
1   2 179.953   9.000  10.00   0.000  0.5000  -1.50
1   2 184.469   4.000  20.00   0.000  0.2500  -0.50
1   2 189.416   6.000  10.00   0.000  0.5000   1.50  0.00  0.00  7.000  0.00 1.00 11.50
1   2 189.416   6.000  20.00   0.000  0.2500   1.50
1   2 194.364   4.000  20.00   0.000  0.2500  -0.50
8   3   0.000   0.000   0.80 200.000
14  3   0.000   2.000
14  3   0.000   2.000   8.00
3   3   2.308   0.000   1.00
4   3  11.551   9.600  18.10   0.000 -1.0000
1   3  13.105  10.000   0.00   0.000  0.5000
6   3  13.105  11.000  12.00  32.710 21.0000
1   3  13.105  18.000  20.00   0.000  0.5000   7.00  0.00  0.00  7.000
1   3  22.911  17.000  20.00   0.000  0.5000   5.50  0.00  0.00  7.000
1   3  32.716  16.000  20.00   0.000  0.5000   4.00  0.00  0.00  7.000
6   3  42.522  14.000  13.00  62.140 21.0000
1   3  42.522  15.000  20.00   0.000  0.5000   1.00  0.00  0.00  7.000
1   3  52.327  14.000  20.00   0.000  0.5000   0.50  0.00  0.00  7.000
1   3  62.133  13.000  20.00   0.000  0.5000   0.00  0.00  0.00  7.000
14  3  72.638   2.000
1   3  75.403  12.000  20.00   0.000  0.5000  -1.00  0.00  0.00  7.000
6   3  75.403  13.000  13.50  95.230 21.0000
1   3  85.420  14.000  20.00   0.000  0.5000   0.75  0.00  0.00  7.000
1   3  95.225  13.000  20.00   0.000  0.5000  -0.50  0.00  0.00  7.000
6   3 105.242  11.500  12.00 115.490 22.0000
1   3 105.242  10.000   0.00   0.000  0.2500
1   3 105.242  12.000  20.00   0.000  0.2500   0.50
1   3 110.313  14.000  20.00   0.000  0.2500   2.25
1   3 115.494  17.000  20.00   0.000  0.2500   5.00
2   3 120.557   0.000   2.00   0.000  0.2500
2   3 125.565   0.000   1.00   0.000  0.5000
3   3 130.913 100.000
14  3 136.271   2.000
4   3 138.530   0.000   8.75   0.000 -1.0000
1   3 139.827   1.000  10.00   0.000  0.5000   7.00  0.00  0.00  7.000
6   3 139.827   8.000   7.50 159.760 11.0000
1   3 139.827   9.000   0.00   0.000  0.5000
1   3 149.898   8.000  10.00   0.000  0.5000  -0.25  0.00  0.00  7.000
1   3 159.758   7.000  11.00   0.000  0.5000   0.50  0.00  0.00  7.000
6   3 169.477   5.000   4.00 189.500 11.0000
1   3 169.477   6.000  10.00   0.000  0.5000  -1.00  0.00  0.00  7.000
1   3 179.196   5.000  10.00   0.000  0.5000  -0.49  0.00  0.00  7.000
1   3 189.495   4.000  10.00   0.000  0.5000   0.00  0.00  0.00  7.000
14  3 200.000   2.000
8   4   0.000   0.000   0.80 200.000
3   4   2.308
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5   4   8.462  12.750  12.75  11.840  0.7500  -1.00  0.00  0.00  0.000  0.00 0.50
9   4   8.530  -4.250  61.00
6   4  13.105   6.500   6.00  37.520 22.0000
6   4  13.105   9.000   8.00  32.710 11.0000
1   4  13.105  11.000  20.00   0.000  0.2500   4.50  0.00  0.00  0.000  0.00 0.75  5.25
1   4  13.105  11.000  10.00   0.000  0.5000  -2.00  0.00  0.00 -9.000  0.00 0.00 -2.00
1   4  17.902   8.000  20.00   0.000  0.2500   1.60
1   4  22.911  10.000  20.00   0.000  0.2500   3.70
1   4  22.911  10.000  10.00   0.000  0.5000  -1.50  0.00  0.00  7.000  0.00 1.00  8.50
1   4  27.708   7.000  20.00   0.000  0.2500   0.80
1   4  32.716   9.000  20.00   0.000  0.2500   2.90
1   4  32.716   9.000  10.00   0.000  0.5000  -1.00  0.00  0.00  7.000  0.00 0.75  9.88
1   4  37.513   6.000  20.00   0.000  0.2500
6   4  42.522   5.500   4.50  67.140 22.0000
6   4  42.522   7.500   6.50  62.130 11.0000
1   4  42.522   8.000  20.00   0.000  0.2500   2.50
1   4  42.522   8.000  10.00   0.000  0.5000  -0.50  0.00  0.00  7.000  0.00 1.00  9.50
1   4  47.319   5.000  20.00   0.000  0.2500  -0.31
1   4  52.327   7.000  20.00   0.000  0.2500   1.90
1   4  52.327   7.000  10.00   0.000  0.5000   0.00  0.00  0.00  7.000  0.00 1.00 11.00
1   4  57.125   4.000  20.00   0.000  0.2500  -0.91
1   4  62.133   6.000  10.00   0.000  0.5000   0.50  0.00  0.00  7.000  0.00 1.00 10.50
1   4  62.133   6.000  20.00   0.000  0.2500   1.30
1   4  67.141   4.000  20.00   0.000  0.2500  -0.50
6   4  75.403   4.500   4.50 100.240 22.0000
1   4  75.403   5.000  20.00   0.000  0.2500   0.50
1   4  75.403   5.000  10.00   0.000  0.5000   1.50  0.00  0.00  7.000  0.00 1.00 12.50
6   4  75.403   6.500   6.50  95.230 11.0000
9   4  75.482  -6.130  53.00
1   4  80.411   4.000  20.00   0.000  0.2500  -0.50
1   4  85.420   7.000  20.00   0.000  0.2500   2.50
1   4  85.420   7.000  10.00   0.000  0.5000  -0.50  0.00  0.00  7.000  0.00 0.75 10.50
1   4  90.217   4.000  20.00   0.000  0.2500  -0.50
1   4  95.225   6.000  20.00   0.000  0.2500   1.50
1   4  95.225   6.000  10.00   0.000  0.5000   0.50  0.00  0.00  7.000  0.00 0.75 10.50
1   4 100.233   4.000  20.00   0.000  0.2500  -0.50
1   4 105.242   5.000  10.00   0.000  0.5000   0.00  1.00
5   4 105.367  -9.250  19.38 139.830  7.7834   0.00 -0.50  0.36  0.000  0.00 0.00  0.00  0.0 1
4   4 107.738  -2.880 999.00 135.140
2   4 115.494   0.000   2.00   0.000  0.2500   0.00  0.00  0.50
6   4 120.557   7.500   8.50 130.770 22.0000
1   4 120.557   7.000  20.00   0.000  0.2500  -0.50
1   4 125.565   9.000  20.00   0.000  0.2500   1.01
1   4 130.774  12.000  20.00   0.000  0.2500   3.50
9   4 138.895  -4.130  61.00
6   4 139.827  10.000   9.50 164.470 22.0000
6   4 139.827  12.500  11.00 159.760 11.0000
1   4 139.827  14.000  11.00   0.000  0.5000  -1.50  0.00  0.00 -9.000  0.00 0.00 -1.50
1   4 139.827  14.000  21.00   0.000  0.2500   4.00  0.00  0.00  0.000  0.00 0.50  4.25
1   4 144.826  11.000  20.00   0.000  0.2500   1.10
9   4 148.523  -4.510  63.25
1   4 149.898  13.000  20.00   0.000  0.2500   3.20
1   4 149.898  13.000  10.00   0.000  0.5000  -1.26  0.00  0.00  7.000  0.00 0.88  9.75
1   4 154.750  10.000  20.00   0.000  0.2500   0.30
1   4 159.758  12.000  20.00   0.000  0.2500   2.40
1   4 159.758  12.000  10.00   0.000  0.5000  -1.00  0.00  0.00  7.000  0.00 1.00  9.00
1   4 164.469   9.000  20.00   0.000  0.2500  -0.50
6   4 169.477   8.500   7.50 194.510 22.0000
6   4 169.477  10.000   8.00 189.740 11.0000
1   4 169.477  11.000  20.00   0.000  0.2500   2.50
1   4 169.477  11.000  10.00   0.000  0.5000  -1.00  0.00  0.00  7.000  0.00 1.00 10.25
1   4 174.188   8.000  20.00   0.000  0.2500  -0.31
1   4 179.196  10.000  20.00   0.000  0.2500   1.89
1   4 179.196  10.000  10.00   0.000  0.5000  -0.96  0.00  0.00  7.000  0.00 1.00  9.25
1   4 184.986   7.000  21.00   0.000  0.2500  -0.88
1   4 189.745   9.000  20.00   0.000  0.2500   1.31
1   4 189.745   9.000  10.00   0.000  0.5000  -1.00  0.00  0.00  7.000  0.00 0.75 10.25
1   4 194.503   7.000  20.00   0.000  0.2500  -0.50
8   5   0.000   0.000   0.80 200.000
14  5   0.000   2.000
14  5   0.000   2.000   8.00
3   5   2.258   0.000   1.00
1   5  13.055  10.000   0.00   0.000  0.5000
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1   5  13.055  12.000  20.00   0.000  0.5000   2.50  1.00
2   5  23.170   0.000   1.00   0.000  0.5000
2   5  33.226   0.000   1.00   0.000  0.5000
2   5  43.281   0.000   0.00   0.000  1.0000
1   5  63.393  17.000  20.00   0.000  0.5000   3.50  1.00  0.00  7.000
14  5  72.543   2.000
4   5  75.595   9.750  17.00   0.000 -1.0000
1   5  76.683  10.000   0.00   0.000  0.5000
6   5  76.683  11.000  11.50  96.380 21.0000
1   5  76.683  18.000  20.00   0.000  0.5000   7.00  0.00  0.00  7.000
1   5  86.533  17.000  20.00   0.000  0.5000   5.75  0.00  0.00  7.000
1   5  96.384  16.000  20.00   0.000  0.5000   4.50  0.00  0.00  7.000
6   5 106.234  14.000  13.00 125.930 21.0000
1   5 106.234  15.000  20.00   0.000  0.5000   1.00  0.00  0.00  7.000
1   5 116.085  14.000  20.00   0.000  0.5000   0.50  0.00  0.00  7.000
1   5 125.935  13.000  20.00   0.000  0.5000   0.00  0.00  0.00  7.000
14  5 136.460   2.000
1   5 139.225  12.000  20.00   0.000  0.5000  -1.00  0.00  0.00  7.000
6   5 139.225  13.000  13.00 159.140 21.0000
1   5 149.281  14.000  20.00   0.000  0.5000   1.00  0.00  0.00  7.000
1   5 159.132  13.000  20.00   0.000  0.5000   0.00  0.00  0.00  7.000
6   5 169.187  11.500  12.00 179.430 22.0000
1   5 169.187  10.000   0.00   0.000  0.2500
1   5 169.187  12.000  20.00   0.000  0.2500   0.50
1   5 174.259  14.000  20.00   0.000  0.2500   2.25
1   5 179.429  16.000  20.00   0.000  0.2500   4.00
2   5 184.447   0.000   2.00   0.000  0.2500
2   5 189.475   0.000   1.00   0.000  0.5000
14  5 200.000   2.000
8   6   0.000   0.000   0.80 200.000
3   6   2.258
1   6  13.055   5.000  10.00   0.000  0.2500   1.00
6   6  13.055   6.000   6.50  38.250 12.0000
4   6  14.515  -5.500 999.00  59.900
1   6  18.083   2.000  10.00   0.000  0.2500   4.10
1   6  23.170   0.000  10.00   0.000  0.2500   6.20
1   6  28.198   2.000  10.00   0.000  0.2500   4.30
1   6  33.226   5.000  10.00   0.000  0.2500   1.40
1   6  38.253   7.000  10.00   0.000  0.2500  -0.50
6   6  43.281   5.500   5.50  68.420 22.0000
1   6  43.281   9.000  20.00   0.000  0.2500   3.50
1   6  48.309   7.000  20.00   0.000  0.2500   1.50
1   6  53.337   5.000  20.00   0.000  0.2500  -0.50
1   6  58.365   7.000  20.00   0.000  0.2500   1.50
1   6  63.393   9.000  20.00   0.000  0.2500   3.50
1   6  63.393   9.000  10.00   0.000  0.5000  -1.00  1.00  0.00  7.000  0.00 1.00 10.25
1   6  68.421   7.000  20.00   0.000  0.2500   1.50
9   6  73.182  -3.130  61.00   0.900
6   6  76.683   6.880   5.50 101.200 22.0000
6   6  76.683   9.000   7.50  96.380 11.0000
1   6  76.683  11.000  20.00   0.000  0.2500   4.13  0.00  0.00  0.000  0.00 1.00  3.75
1   6  76.683  11.000  10.00   0.000  0.5000  -2.00  0.00  0.00 -9.000  0.00 0.00 -2.00
1   6  81.506   8.000  20.00   0.000  0.2500   1.40
1   6  86.533  10.000  10.00   0.000  0.5000  -1.75
1   6  86.533  10.000  20.00   0.000  0.2500   3.68  0.00  0.00  7.000  0.00 1.00  4.25
1   6  91.356   7.000  20.00   0.000  0.2500   0.95
1   6  96.384   9.000  10.00   0.000  0.5000  -1.50  0.00  0.00  7.000  0.00 1.00  9.50
1   6  96.384   9.000  20.00   0.000  0.2500   3.23
1   6 101.206   6.000  20.00   0.000  0.2500   0.50
6   6 106.234   5.500   5.00 130.970 22.0000
6   6 106.234   7.500   6.00 125.930 11.0000
1   6 106.234   8.000  20.00   0.000  0.2500   2.50
1   6 106.234   8.000  10.00   0.000  0.5000  -0.50  0.00  0.00  7.000  0.00 1.00  9.50
1   6 111.057   5.000  20.00   0.000  0.2500  -0.40
1   6 116.085   7.000  20.00   0.000  0.2500   1.70
1   6 116.085   7.000  10.00   0.000  0.5000  -0.25  0.00  0.00  7.000  0.00 0.75 10.75
1   6 120.907   4.000  20.00   0.000  0.2500  -1.20
1   6 125.935   6.000  10.00   0.000  0.5000   0.00  0.00  0.00  7.000  0.00 1.00 10.00
1   6 125.935   6.000  20.00   0.000  0.2500   0.90
1   6 130.963   4.000  20.00   0.000  0.2500  -1.00
9   6 138.803  -5.750  53.00
1   6 139.225   5.000  10.00   0.000  0.5000   1.00  0.00  0.00  7.000  0.00 1.00 12.00
6   6 139.225   5.000   4.50 164.160 22.0000
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1   6 139.225   5.000  20.00   0.000  0.2500
6   6 139.225   6.000   6.50 159.140 11.0000
1   6 144.253   4.000  20.00   0.000  0.2500  -0.90
1   6 149.281   7.000  10.00   0.000  0.5000  -0.75  0.00  0.00  7.000  0.00 1.00 10.25
1   6 149.281   7.000  20.00   0.000  0.2500   2.20
1   6 154.104   4.000  20.00   0.000  0.2500  -0.70
1   6 159.132   6.000  10.00   0.000  0.5000   0.50  0.00  0.00  7.000  0.00 0.75 10.50
1   6 159.132   6.000  20.00   0.000  0.2500   1.40
1   6 164.160   4.000  20.00   0.000  0.2500  -0.50
1   6 169.187   5.000  10.00   0.000  0.5000   0.00  1.00 -0.25
5   6 169.781  -9.250  16.25 199.250  9.2134   0.00 -0.44  0.48  0.000  0.00 0.00  0.00  0.0 1
4   6 171.859  -2.380 999.00 197.720
2   6 179.429   0.000   2.00   0.000  0.2500
1   6 184.447   5.000  10.00   0.000  0.2500   2.00
6   6 184.447   7.000   8.50 194.500 12.0000
1   6 189.475   7.000  10.00   0.000  0.2500   0.75
1   6 194.503   9.000  10.00   0.000  0.2500  -0.50
8   7   0.000   0.000   0.80 200.000
14  7   0.000   2.000   8.00
14  7   0.000   2.000
3   7   1.542   0.000   1.00
1   7  13.010   6.000   0.00   0.000  0.5000
1   7  13.010  11.000  20.00   0.000  0.5000   4.50  1.00  0.00  7.000
2   7  23.152   0.000   1.00   0.000  0.5000
1   7  33.082   6.000   0.00   0.000  0.5000
1   7  33.082  11.000  20.00   0.000  0.5000   5.50  1.00  0.00  7.000
1   7  43.224   6.000   0.00   0.000  0.5000
1   7  43.224  14.000  20.00   0.000  0.5000   7.50  1.00  0.00  7.000
2   7  53.747   0.000   1.00   0.000  0.5000
1   7  63.678   6.000   0.00   0.000  0.5000
1   7  63.678  12.000  20.00   0.000  0.5000   6.50  1.00  0.00  7.000
14  7  73.860   2.000
1   7  76.483   6.000   0.00   0.000  0.5000
1   7  76.483  13.000  20.00   0.000  0.5000   7.00  1.00  0.00  7.000
2   7  87.508   0.000   1.00   0.000  0.5000
6   7  97.449  13.500  14.00 102.460 22.0000
1   7  97.449  13.000  20.00   0.000  0.2500  -0.50
1   7 102.467  15.000  20.00   0.000  0.2500   1.00  0.00  0.00  0.000  0.00 0.00  0.00  0.0 0 0 123.46 123.46
6   7 107.432  11.500  11.50 132.740 22.0000
1   7 107.432  12.000  20.00   0.000  0.2500   0.50
1   7 112.882  14.000  23.02   0.000  0.2500   2.50
1   7 117.847  12.000  20.00   0.000  0.2500   0.50
1   7 122.813  14.000  20.00   0.000  0.2500   2.50
1   7 127.778  12.000  20.00   0.000  0.2500   0.50
1   7 132.743  14.000  20.00   0.000  0.2500   2.50
14  7 137.750   2.000
1   7 140.373  11.000  20.00   0.000  0.2500  -0.50
6   7 140.373  11.500  11.50 165.200 22.0000
1   7 145.340  15.000  20.00   0.000  0.2500   3.50
1   7 150.305  11.000  20.00   0.000  0.2500  -0.50
1   7 155.270  15.000  20.00   0.000  0.2500   3.50
4   7 155.270  20.560 999.00 194.990 -1.0000
1   7 160.235  11.000  20.00   0.000  0.2500  -0.50
1   7 165.201  14.000  20.00   0.000  0.2500   2.50
1   7 170.167   7.000  20.00   0.000  0.2500  -0.50
6   7 170.167   7.500   7.50 194.990 22.0000
1   7 175.132  13.000  20.00   0.000  0.2500   5.50
1   7 180.097   7.000  20.00   0.000  0.2500  -0.50
1   7 185.063  14.000  20.00   0.000  0.2500   6.50
1   7 190.029   7.000  20.00   0.000  0.2500  -0.50
1   7 194.994  13.000  20.00   0.000  0.2500   5.50
14  7 200.000   2.000
8   8   0.000   0.000   0.80 200.000
3   8   1.542
6   8  13.010   4.500   4.00  38.260 22.0000
1   8  13.010   9.000  10.00   0.000  0.5000  -1.00  1.00  0.00  7.000  0.00 1.00 10.00
1   8  13.010   9.000  20.00   0.000  0.2500   4.50
1   8  18.186   4.000  20.00   0.000  0.2500  -0.40
1   8  23.152   3.000  20.00   0.000  0.2500  -1.30
2   8  23.152   4.000   1.00   0.000  0.5000
1   8  28.117   4.000  20.00   0.000  0.2500  -0.20
1   8  33.082   8.000  20.00   0.000  0.2500   3.90
1   8  33.082   8.000  10.00   0.000  0.5000  -1.00  1.00  0.00  7.000  0.00 1.00  9.00
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1   8  38.259   4.000  20.00   0.000  0.2500
6   8  43.224   4.000   4.00  68.850 22.0000
1   8  43.224   7.000  20.00   0.000  0.2500   3.00
1   8  43.224   7.000  10.00   0.000  0.5000  -0.50  1.00  0.00  7.000  0.00 1.00 10.50
1   8  48.781   4.000  20.00   0.000  0.2500
2   8  53.747   2.000   1.00   0.000  0.5000
1   8  53.747   3.000  20.00   0.000  0.2500  -1.00
1   8  58.712   4.000  20.00   0.000  0.2500
1   8  63.678   6.000  20.00   0.000  0.2500   2.00
1   8  63.678   6.000  10.00   0.000  0.5000  -0.50  1.00  0.00  7.000  0.00 0.75  9.50
1   8  68.854   4.000  20.00   0.000  0.2500
6   8  76.483   2.500   2.50  97.450 21.0000   0.00  0.00 11.00 76.490 92.48
1   8  76.483   5.000  10.00   0.000  0.5000   0.50  1.00  0.00  7.000  0.00 0.75 11.50
1   8  76.483   5.000  20.00   0.000  0.2500   2.50
1   8  81.660   3.000  20.00   0.000  0.2500   0.50
1   8  87.508   2.000  22.00   0.000  0.2500  -0.50
2   8  87.690   2.000   1.00   0.000  0.5000   0.00  0.00  0.24
1   8  92.483   3.000  20.00   0.000  0.2500   0.50
1   8  97.449   5.000  20.00   0.000  0.2500   2.50
1   8  97.449   5.000  10.00   0.000  0.5000   0.00  1.00  0.00  7.000  0.00 0.75 11.00
4   8 108.133  -3.190 999.00 143.830
1   8 107.432   5.000  10.00   0.000  0.5000   1.00  0.00  0.00  7.000
6   8 107.432   6.000   7.00 127.780 11.0000
1   8 117.847   4.000  12.00   0.000  0.5000   2.51  0.00  0.00  7.000
1   8 117.847   6.000   0.00   0.000  0.5000
1   8 127.778   5.000  10.00   0.000  0.5000   2.00  0.00  0.00  7.000
1   8 127.778   7.000   0.00   0.000  0.5000
1   8 140.373   5.000  10.00   0.000  0.5000   3.00  0.00  0.00  7.000
6   8 140.373   8.000   7.00 160.240 11.0000
1   8 140.373   9.000   0.00   0.000  0.5000
1   8 150.305   6.000  10.00   0.000  0.5000   1.50  0.00  0.00  7.000
1   8 150.305   8.000   0.00   0.000  0.5000
1   8 160.235   5.000  10.00   0.000  0.5000   2.00  0.00  0.00  7.000
1   8 160.235   7.000   0.00   0.000  0.5000
1   8 170.167   4.000  12.00   0.000  0.5000   2.00  0.00  0.00  7.000
1   8 170.167   6.000   0.00   0.000  0.5000
6   8 170.167   6.000   6.00 190.030 11.0000
1   8 180.097   4.000  10.00   0.000  0.5000   2.00  0.00  0.00  7.000
1   8 180.097   7.000   0.00   0.000  0.5000
1   8 190.029   4.000  10.00   0.000  0.5000   2.00  0.00  0.00  7.000
1   8 190.029   6.000   0.00   0.000  0.5000
8   9   0.000   0.000   0.80 200.000
14  9   0.000   2.000
14  9   0.000   2.000   8.00
3   9   2.208   0.000   1.00
1   9  13.278   6.000   0.00   0.000  0.5000
1   9  13.278  13.000  20.00   0.000  0.5000   7.50  1.00  0.00  7.000
2   9  24.014   0.000   1.00   0.000  0.5000
1   9  33.848  13.000  20.00   0.000  0.2500  -0.50
6   9  33.848  13.500  14.00  38.920 22.0000
1   9  38.928  15.000  20.00   0.000  0.2500   1.00
6   9  43.771  11.500  11.50  68.540 22.0000
1   9  43.771  12.000  20.00   0.000  0.2500   0.50
1   9  48.980  14.000  23.02   0.000  0.2500   2.50
1   9  53.824  12.000  20.00   0.000  0.2500   0.50
1   9  58.761  14.000  20.00   0.000  0.2500   2.50
1   9  63.604  12.000  20.00   0.000  0.2500   0.50
1   9  68.542  14.000  20.00   0.000  0.2500   2.50
14  9  73.801   2.000
6   9  80.767  10.000  10.00 105.260 22.0000
1   9  80.767  11.000  20.00   0.000  0.2500   1.00
1   9  85.704  15.000  20.00   0.000  0.2500   5.00
1   9  90.548  11.000  20.00   0.000  0.2500   1.00
1   9  95.485  15.000  20.00   0.000  0.2500   5.00
1   9 100.329  11.000  20.00   0.000  0.2500   1.00
1   9 105.266  15.000  20.00   0.000  0.2500   5.00
6   9 109.955   7.500   7.50 133.510 22.0000
1   9 109.955   7.000  20.00   0.000  0.2500  -0.50
1   9 114.810  14.000  20.00   0.000  0.2500   6.50
1   9 119.307   7.000  20.00   0.000  0.2500  -0.50
1   9 124.162  13.000  20.00   0.000  0.2500   5.50
1   9 128.659   7.000  20.00   0.000  0.2500  -0.50
1   9 133.514  12.000  20.00   0.000  0.2500   4.50
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14  9 138.784   2.000
6   9 141.619   9.500   9.50 165.180 22.0000
1   9 141.619  10.000  20.00   0.000  0.2500   0.50
1   9 146.474  15.000  20.00   0.000  0.2500   5.50
1   9 150.972  10.000  20.00   0.000  0.2500   0.50
1   9 155.826  14.000  20.00   0.000  0.2500   4.50
1   9 160.324  10.000  20.00   0.000  0.2500   0.50
1   9 165.179  13.000  20.00   0.000  0.2500   3.50
1   9 170.022  12.000  20.00   0.000  0.5000   0.50  1.00
2   9 179.856   0.000   1.00   0.000  0.5000   0.00  0.00  0.53
1   9 189.690   6.000   0.00   0.000  0.5000
1   9 189.690  10.000  20.00   0.000  0.5000   5.00  1.00  0.00  7.000
14  9 200.000   2.000
8  10   0.000   0.000   0.80 200.000
3  10   2.208
6  10  13.278   3.500   3.50  33.850 21.0000   0.00  0.00 11.00 13.280 28.93
1  10  13.278   5.000  20.00   0.000  0.2500   1.50
1  10  13.278   5.000  10.00   0.000  0.5000   0.00  1.00  0.00  7.000  0.00 1.00 11.00
1  10  18.195   3.000  20.00   0.000  0.2500  -0.50
1  10  24.014   2.000  22.00   0.000  0.2500  -1.50
2  10  24.014   2.000   1.00   0.000  0.5000
1  10  28.931   3.000  20.00   0.000  0.2500  -0.50
1  10  33.848   5.000  20.00   0.000  0.5000   1.50
1  10  33.848   5.000  10.00   0.000  0.5000  -0.50  1.00  0.00  7.000  0.00 1.00 10.50
1  10  43.771   5.000  10.00   0.000  0.5000   1.00  0.00  0.00  7.000
6  10  43.771   6.000   7.00  63.600 11.0000
4  10  53.105  -2.330 999.00 108.470
1  10  53.824   4.000  12.00   0.000  0.5000   2.51  0.00  0.00  7.000
1  10  53.824   6.000   0.00   0.000  0.5000
1  10  63.604   5.000  10.00   0.000  0.5000   2.00  0.00  0.00  7.000
1  10  63.604   7.000   0.00   0.000  0.5000
1  10  76.069 109.000  10.00   0.000 65.0000 100.00  1.00
5  10  77.302   8.270   7.90  80.370 -0.7000   0.00 -1.00  0.00  0.000  0.00 0.50
1  10  80.767   5.000  10.00   0.000  0.5000   2.00  0.00  0.00  7.000
6  10  80.767   7.000   7.00 100.330 11.0000
1  10  80.767   8.000   0.00   0.000  0.5000
1  10  90.548   5.000  10.00   0.000  0.5000   2.00  0.00  0.00  7.000
1  10  90.548   7.000   0.00   0.000  0.5000
1  10 100.329   5.000  10.00   0.000  0.5000   2.00  0.00  0.00  7.000
1  10 100.329   8.000   0.00   0.000  0.5000
1  10 109.955   4.000  13.00   0.000  0.5000   4.00  0.00  0.00  7.000
6  10 109.955   8.000   8.00 128.660 11.0000
1  10 109.955   8.000   0.00   0.000  0.5000
4  10 111.878  -2.330 999.00 161.430 -1.0000
1  10 119.307   4.000  10.00   0.000  0.5000   4.00  0.00  0.00  7.000
1  10 119.307  10.000   0.00   0.000  0.5000
1  10 128.659   4.000  10.00   0.000  0.5000   4.00  0.00  0.00  7.000
1  10 128.659   9.000   0.00   0.000  0.5000
1  10 141.619   4.000  10.00   0.000  0.5000   2.50  0.00  0.00  7.000
6  10 141.619   6.500   5.88 160.320 11.0000
1  10 141.619   8.000   0.00   0.000  0.5000
1  10 150.972   4.000  10.00   0.000  0.5000   2.19  0.00  0.00  7.000
1  10 150.972   7.000   0.00   0.000  0.5000
1  10 160.324   4.000  10.00   0.000  0.5000   1.87  0.00  0.00  7.000
1  10 160.324   6.000   0.00   0.000  0.5000
6  10 170.022   4.000   4.00 194.360 22.0000
1  10 170.022   5.000  10.00   0.000  0.5000   0.50  1.00  0.00  7.000  0.00 1.00 11.50
1  10 170.022   5.000  20.00   0.000  0.2500   1.00
1  10 174.939   4.000  20.00   0.000  0.2500
1  10 179.856   3.000  20.00   0.000  0.2500  -1.00
2  10 179.856   2.000   1.00   0.000  0.5000
1  10 184.773   4.000  20.00   0.000  0.2500
1  10 189.690  10.000  10.00   0.000  0.5000  -1.00  1.00  0.50  7.000  0.00 1.00  9.00
1  10 189.690  10.000  20.00   0.000  0.2500   6.00  0.00  0.50
1  10 194.364   3.000  20.00   0.000  0.2500  -1.00
8  11  17.021   0.000   0.80 200.000
14 11  17.021   2.000
14 11  17.021   2.000   8.00
3  11  19.379   0.000   1.00
18 11  26.239   0.000   6.00   8.000
2  11  31.654   0.000  -2.00   0.000  3.0000   0.00 54.64
14 11  85.533   2.000
2  11  87.270   0.000   0.00   0.000  1.0000   0.00  0.00  0.26
```

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2  11 106.478   0.000   1.00   0.000  0.5000
2  11 113.972   0.000   0.00   0.000  1.0000
1  11 134.703   6.000   0.00   0.000  0.5000
1  11 134.703  10.000  20.00   0.000  0.5000   4.00  1.00  0.00  7.000
14 11 141.180   2.000
1  11 144.173   6.000   0.00   0.000  0.5000
1  11 144.173  11.000  20.00   0.000  0.5000   5.00  1.00  0.00  7.000
2  11 152.328   0.000   1.00   0.000  0.5000   0.00  0.00  0.25
1  11 162.591   6.000   0.00   0.000  0.5000
1  11 162.591  11.000  20.00   0.000  0.5000   5.00  1.00  0.00  7.000
1  11 171.092   6.000   0.00   0.000  0.5000
1  11 171.092  14.000  20.00   0.000  0.5000   8.00  1.00  0.00  7.000
2  11 179.347   0.000   1.00   0.000  0.5000
1  11 189.611   6.000   0.00   0.000  0.5000
1  11 189.611  12.000  20.00   0.000  0.5000   6.00  1.00  0.00  7.000
14 11 200.000   2.000
8  12  17.021   0.050   0.80 200.000
3  12  19.379
18 12  26.239   0.000   6.00   8.000
9  12  30.966  -4.560  53.00
1  12  31.654   5.000  10.00   0.000  0.2500   0.50
6  12  31.654   5.500   5.50  55.610 12.0000
5  12  34.431  13.350  12.56 135.740  3.8358   0.00  3.00  0.60
4  12  34.818  -3.760 999.00 130.740
1  12  36.880   6.000  11.93   0.000  0.2500  -0.50
1  12  40.627   5.000  10.00   0.000  0.2500   0.50
1  12  46.245   4.000  12.92   0.000  0.2500   1.50
1  12  51.862   3.000  12.92   0.000  0.2500   2.50
1  12  55.609   4.000  10.00   0.000  0.2500   1.50
1  12  59.356   5.000  10.00   0.000  0.2500   0.50
6  12  59.356   5.500   5.50  80.720 12.0000
1  12  63.689   6.000  10.00   0.000  0.2500  -0.50
1  12  67.947   5.000  10.00   0.000  0.2500   0.50
1  12  72.205   4.000  10.00   0.000  0.2500   1.50
1  12  76.179   3.000  10.00   0.000  0.2500   2.50
1  12  80.721   4.000  10.00   0.000  0.2500   1.50
1  12  87.270   5.000  10.00   0.000  0.2500   1.00  0.00 -0.50
6  12  87.270   6.000   6.00 110.230 12.0000   0.00  0.00  0.00  0.000  0.00 0.00 -0.50
1  12  92.371   6.000  11.93   0.000  0.2500   0.00  0.00 -0.25
1  12  95.493   5.000  10.00   0.000  0.2500   1.00  0.00  0.50
1  12 100.861   4.000  12.93   0.000  0.2500   2.00  0.00  0.50
1  12 106.738   3.000  12.94   0.000  0.2500   3.00  0.00 -0.25
1  12 110.225   4.000  10.00   0.000  0.2500   2.00
1  12 113.972   5.000  10.00   0.000  0.2500   1.00
6  12 113.972   6.000   5.50 129.040 12.0000
1  12 119.633   6.000  13.95   0.000  0.2500  -0.20
1  12 123.630   5.000  10.00   0.000  0.2500   0.68
1  12 129.042   4.000  13.94   0.000  0.2500   1.50
1  12 134.903   3.000  13.92   0.000  0.5000   5.00  1.00  0.00  7.000  0.00 1.00 15.50
1  12 134.903  10.000   3.91   0.000  0.5000
6  12 144.172   4.500   4.50 165.960 22.0000
1  12 144.172   9.000  20.00   0.000  0.2500   4.50
1  12 144.172   9.000  10.00   0.000  0.5000  -1.00  1.00  0.00  7.000  0.00 1.00 10.00
1  12 147.196   4.000  20.00   0.000  0.2500  -0.50  0.00  0.75
1  12 152.328   3.000  20.00   0.000  0.2500  -1.50
2  12 152.328   4.000   1.00   0.000  0.5000
1  12 157.459   4.000  20.00   0.000  0.2500  -0.50
1  12 162.591   8.000  20.00   0.000  0.2500   3.50
1  12 162.591   8.000  10.00   0.000  0.5000  -1.00  1.00  0.00  7.000  0.00 1.00  9.00
1  12 165.960   4.000  20.00   0.000  0.2500  -0.50
6  12 171.092   4.000   4.00 194.740 22.0000   0.00  0.00  0.00  0.000  0.00 0.00  0.00 -0.5
1  12 171.092   7.000  10.00   0.000  0.5000  -0.50  1.00  0.00  7.000  0.00 1.00 10.50
1  12 171.092   7.000  20.00   0.000  0.2500   3.00
1  12 174.215   4.000  20.00   0.000  0.2500   0.00  0.00  0.75
2  12 179.347   2.000   1.00   0.000  0.5000
1  12 179.347   3.000  20.00   0.000  0.2500  -1.00
1  12 184.479   4.000  20.00   0.000  0.2500
1  12 189.611   6.000  20.00   0.000  0.2500   2.00
1  12 189.611   6.000  10.00   0.000  0.5000  -0.50  1.00  0.00  7.000  0.00 1.00  9.50
1  12 194.743   4.000  20.00   0.000  0.2500   0.00  0.00 -0.50
t  12  82.031  35.625   1.00   1.405
_00Spinning Song
t  12  88.636  30.625   1.00   0.966
```

```
_00Op. 67, No. 4
t  12  74.962  26.625   1.00   0.878
_00(From _02Songs without Words_00, 1845)
t  12 167.883  19.000   1.00   1.000  0.0000   0.00  0.00  0.00 -1.134
_00Felix Mendelssohn
t  12  27.650  16.000   1.00   1.054  0.0000   0.00  0.00  0.00 -1.134
_00Presto
10 10   0.000  13.000   4.00   0.000  1.0000
10  8   0.000  13.000   7.00   0.000  1.0000
10  6  -1.000  13.000  10.00   0.000  1.0000
10  4  -1.000  13.000  13.00   0.000  1.0000
10  2  -1.000  13.000  16.00   0.000  1.0000
```

Using the above PMX data, the command:

`./scrstaffqq -pf spin1.pmx > spin1.vec`

will generate the following vector-graphic information for each staff line on the page.

```
%SCORE%8. 1.0 .000 .00 .80 200.00
4      315.25       6112.75      4814.25      6112.75
4      315.25       6070.75      4814.25      6070.75
4      315.25       6028.75      4814.25      6028.75
4      315.25       5986.75      4814.25      5986.75
4      315.25       5944.75      4814.25      5944.75
%SCORE%8. 2.0 .000 .00 .80 200.00
4      315.25       5640.75      4814.25      5640.75
4      315.25       5598.75      4814.25      5598.75
4      315.25       5556.75      4814.25      5556.75
4      315.25       5514.75      4814.25      5514.75
4      315.25       5472.75      4814.25      5472.75
%SCORE%8. 3.0 .000 .00 .80 200.00
4      315.25       5167.75      4814.25      5167.75
4      315.25       5125.75      4814.25      5125.75
4      315.25       5083.75      4814.25      5083.75
4      315.25       5041.75      4814.25      5041.75
4      315.25       4999.75      4814.25      4999.75
%SCORE%8. 4.0 .000 .00 .80 200.00
4      315.25       4695.75      4814.25      4695.75
4      315.25       4653.75      4814.25      4653.75
4      315.25       4611.75      4814.25      4611.75
4      315.25       4569.75      4814.25      4569.75
4      315.25       4527.75      4814.25      4527.75
%SCORE%8. 5.0 .000 .00 .80 200.00
4      315.25       4222.75      4814.25      4222.75
4      315.25       4180.75      4814.25      4180.75
4      315.25       4138.75      4814.25      4138.75
4      315.25       4096.75      4814.25      4096.75
4      315.25       4054.75      4814.25      4054.75
%SCORE%8. 6.0 .000 .00 .80 200.00
4      315.25       3750.75      4814.25      3750.75
4      315.25       3708.75      4814.25      3708.75
4      315.25       3666.75      4814.25      3666.75
4      315.25       3624.75      4814.25      3624.75
4      315.25       3582.75      4814.25      3582.75
%SCORE%8. 7.0 .000 .00 .80 200.00
4      315.25       3277.75      4814.25      3277.75
4      315.25       3235.75      4814.25      3235.75
```

```
4      315.25       3193.75      4814.25      3193.75
4      315.25       3151.75      4814.25      3151.75
4      315.25       3109.75      4814.25      3109.75
%SCORE%8. 8.0 .000 .00 .80 200.00
4      315.25       2805.75      4814.25      2805.75
4      315.25       2763.75      4814.25      2763.75
4      315.25       2721.75      4814.25      2721.75
4      315.25       2679.75      4814.25      2679.75
4      315.25       2636.75      4814.25      2636.75
%SCORE%8. 9.0 .000 .00 .80 200.00
4      315.25       2332.75      4814.25      2332.75
4      315.25       2290.75      4814.25      2290.75
4      315.25       2248.75      4814.25      2248.75
4      315.25       2206.75      4814.25      2206.75
4      315.25       2164.75      4814.25      2164.75
%SCORE%8. 10.0 .000 .00 .80 200.00
4      315.25       1860.75      4814.25      1860.75
4      315.25       1818.75      4814.25      1818.75
4      315.25       1776.75      4814.25      1776.75
4      315.25       1734.75      4814.25      1734.75
4      315.25       1692.75      4814.25      1692.75
%SCORE%8. 11.0 17.021 .00 .80 200.00
4      697.25       1387.75      4814.25      1387.75
4      697.25       1345.75      4814.25      1345.75
4      697.25       1303.75      4814.25      1303.75
4      697.25       1261.75      4814.25      1261.75
4      697.25       1219.75      4814.25      1219.75
%SCORE%8. 12.0 17.021 .05 .80 200.00
4      697.25       913.75       4814.25      913.75
4      697.25       871.75       4814.25      871.75
4      697.25       829.75       4814.25      829.75
4      697.25       787.75       4814.25      787.75
4      697.25       745.75       4814.25      745.75
```

This data can in turn be sent through the *hilitestaff* program (page 43) to highlight staves in a bitmapped image (as done in Figure 14 on page 47), or using the `-d` option, it can produce a list of rectangular areas in the image which cover each staff/system:

```
./hilitestaff -d spin1.vec
```

```
315,5942 4814,6114
315,5470 4814,5642
315,4997 4814,5169
315,4525 4814,4697
315,4052 4814,4224
315,3580 4814,3752
315,3107 4814,3279
315,2635 4814,2807
315,2162 4814,2334
315,1690 4814,1862
697,1217 4814,1389
697,743 4814,915
```

The highlighted grouping of every two staves in Figure 14 was done by adding the `-s 2` option to the *hilitestaff* command:

```
./hilitestaff -s2 -d spine1.vec
```

```
315,5470 4814,6114
315,4525 4814,5169
315,3580 4814,4224
315,2635 4814,3279
315,1690 4814,2334
697,743 4814,1389
```

Generalized highlighting by system would require parsing both barline and staff objects in the original PMX data. SCORE has no explicit method for labeling systems, so system groupings of staves must be done by examining how the staves are connected to each other with barlines. When there are no barlines in common between two adjacent staves, a break between systems can reliably be inferred. The C code at the end of Appendix III demonstrates how to identify the system grouping for staves. See the `calculateSystemAssignments()` function on page 77. Here is the demonstrated output at the end of Appendix III where systems are automatically identified for this same musical example:

```
System 1:   697,743 4814,1389
      Staff 12:   697,743 4814,915
      Staff 11:   697,1217 4814,1389
System 2:   315,1690 4814,2334
      Staff 10:   315,1690 4814,1862
      Staff 9:    315,2162 4814,2334
System 3:   315,2635 4814,3279
      Staff 8:    315,2635 4814,2807
      Staff 7:    315,3107 4814,3279
System 4:   315,3579 4814,4224
      Staff 6:    315,3579 4814,3752
      Staff 5:    315,4052 4814,4224
System 5:   315,4525 4814,5169
      Staff 4:    315,4525 4814,4697
      Staff 3:    315,4997 4814,5169
System 6:   315,5470 4814,6114
      Staff 2:    315,5470 4814,5642
      Staff 1:    315,5942 4814,6114
```