Macro-uniformity ruler software

Introduction

The “w11macro” software was written as part of the INCITS W1.1 Macro-uniformity activity to develop a standard for assessment of macro-uniformity of prints. The software serves a couple of purposes:

- Generation of digital files (BMP images) for printing of the W1.1 macro-uniformity ruler. The ruler can be successfully printed only on high quality printers, for example photo-quality ink jet printers. The software contains calibration functionality so that accurate scale reproductions can be obtained.
- Generation of digital files (BMP images) with simulated printer defects, e.g. streaks, bands, mottle. These image files are intended to be printed and used to test the complete process of the macro-uniformity ruler. The prints with specific simulated defects should be evaluated with the macro-uniformity ruler, and the results compared to published reference values.
- The generated digital images contain analytical test elements (surrounding the main nominally uniform region) which are intended to be used to verify the print generation process. The software is intended to also provide very basic tools to measure the conformance of these analytical elements, e.g. by measuring L* amplitude of several banding patterns. However, the current version of the software does not provide this functionality.

This document is intended to explain how to use the software for generation of macro-uniformity ruler images, and for generation of specific simulated defects.

The w11macro software runs on both Windows and Mac OS X platforms, but this document limits the explanation to Windows platforms.

First there is a section that explains how to install the software.

Then follows a section with step-by-step instructions on how to calibrate for your printer and generate the ruler images. It is recommended that you initially follow this process exactly, using the included CIELab data files (instead of measurements for your own printer). This way you can test that all parts of the software works. When you are satisfied that it works, then you can return to Step B, and perform the CIELAB measurements that are required in order to generate accurate images for your printer.

Then follows a section that explains how to generate all the image files for the macro-uniformity ruler.

Then follows a section that explains the command-line interface to the w11macro software. This interface is very simple, because all input is read from configuration files (called *MIO* files). This section also explains the syntax of the MIO files, and all the acceptable input parameters, which control the image generation.

Then follows a section that provides an example of how to generate images with simulated defects. For this to work, you must have gone through the calibration steps explained in the earlier sections.

Installation

Unzip the archive, placing the contents into `C:\w11macro`, such that there are directories `C:\w11macro\apps`, `C:\w11macro\doc` etc. The software will function fine if installed elsewhere, but you would have to slightly modify pathnames in some of the input files. In this manual we will assume the files are installed in that directory. The directory contains these subdirectories:

- `apps`: Contains the executable program `w11macro.exe`. As of version 0.3 dependencies on 3rd party libraries (such as libtiff) have been removed, and the program is statically linked, such that no DLLs are necessary.
- `calibration_input:` Holds input files needed to generate printer calibration files. These input files are obtained by spectrophotometer measurements on the calibration test pattern. One file in this directory, `w11_calibration_cin.data`, will be written by the application when it is used to generate the calibration test pattern.
- `fonts`: Contains the font used when adding labels to generated images. Not used by version 0.3.0, but support for this may be added back in a future version.
- `generated_calibrations`: Holds generated files related to printer calibration.
- `generated_scales`: Holds generated scale images.
- `images`: empty folder for generated images.
- `mio_scale`: Contains input files for creating the macrouniformity scale images.
- `mio_setup`: Contains input files for the tutorial in this document, including several steps for printer calibration.

Some of the subdirectories contain files named in the style `ref__xxx` which are for use by the tutorial in this document only.

Calibration and scale samples - a step by step example

The input files (with CIELab measurements) that are used for this tutorial are supplied with the distribution, so if you wish, you can follow along using those input files. Later on, you can return to step B, make your own CIELab measurements and according modifications to the input files, such that the generated images are calibrated for your own printer.

The examples that follow all use the command line to issue commands of the form:

```
w11macro.exe --mio path_to_some_mio_file.txt
```

which causes the program to read all instructions from the specified “MIO” input file. The MIO file syntax and instructions are described in detail in a later section.

Step A: Create the printer calibration test pattern

From a terminal window, go to the `C:\w11macro\apps` directory. Enter:

```
w11macro.exe --mio ..\mio_setup\mio_step_a_calibration_testpattern.txt
```

which should lead to the following output:

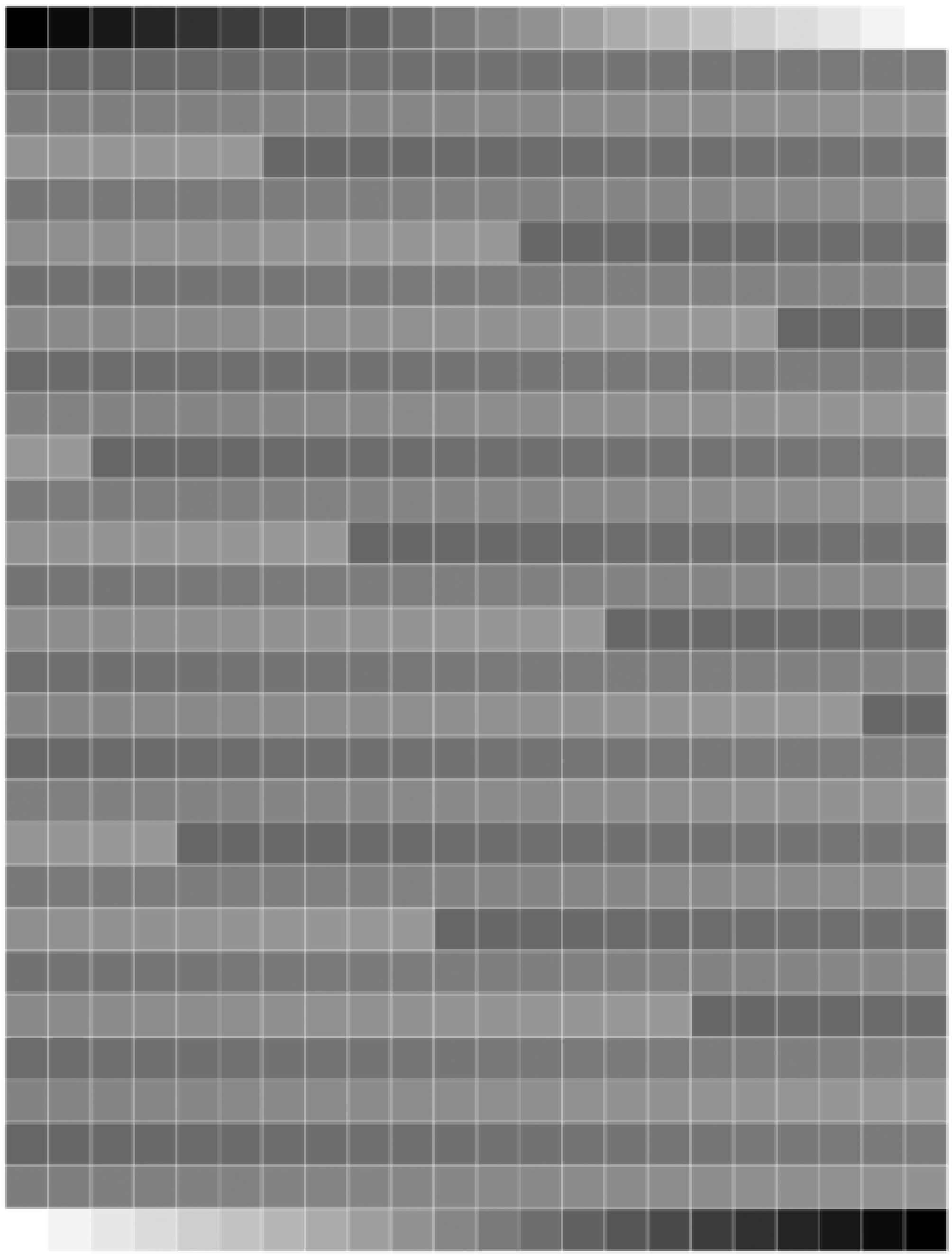
```
Wrote image <C:\w11macro\generated_calibrations\calib_x2550_y3300.bmp>
```

Check that the file C:`\w11macro\calibration_input\w11_calibration_cin.data` has been generated. This file contains a table of input values for the patches on the generated calibration test pattern. The first column in this file contains an arbitrary index. The second column is the row-index on the test pattern. The third column is the column-index on the test pattern. The fourth column is the input value to the printer, as a Y value from 0 to 100, before mapping to an 8 bit value from 0 to 255.

Check that the file C:`\w11macro\generated_calibrations\calib_x2550_y3300.iw11.bmp` has been created and looks similar to this:

Note that version 0.3.0 does not support text annotation of the generated images. This feature may be added back again in a later version.

2008.09.10.22.38.30



Step B: Print and measure the calibration test pattern.

As a tutorial, you can skip this step, and instead perform the next step, C, by using the supplied `ref_xxx` calibration input files—this will, of course, not calibrate for your printer, it will only teach you how to use the software.

1. Print the test pattern `calib_x2550_y3300.bmp` with the selected printer options.
2. Measure CIE XYZ values on the prints. Looking at the print in portrait orientation, with the date at the top left, start measurements at the top-right patch and move left until all 22 patches of the top row have been measured. Then go to the second row from the top, starting at the right, finishing at the left. And so on.
3. Put the measured CIE XYZ data into the format required by the program. The format is illustrated by the files named `ref__nnnnnn.it8` in the `C:\w11macro\calibration_input` directory. The structure of the file must be as follows:
    - 3.1. Any number of header lines
    - 3.2. A line containing "BEGIN_DATA"
    - 3.3. 638 lines each with measurements from one patch, and in the measurement order specified above. Each line must have 7 numbers separated by whitespace:
        - 3.3.1. The measurement index running from 1 to 638.
        - 3.3.2. Any number (will be ignored)
        - 3.3.3. Any number (will be ignored)
        - 3.3.4. Any number (will be ignored)
        - 3.3.5. CIE X value
        - 3.3.6. CIE Y value
        - 3.3.7. CIE Z value
    - 3.4. A line containing "END_DATA"
    - 3.5. Any number of additional lines which will be ignored.

In order to reduce the effect of noise, you can repeat the above steps multiple times. For example, print 3 copies of the calibration test pattern, and measure each copy twice. This will lead to 6 XYZ data files, which can all be used in the following step.

Example of data file:

```
Rene - TRC level chart 22x29

ORIGINATOR           ""
DESCRIPTOR           "Output Characterisation"
CREATED              "6/26/2008"

INSTRUMENTATION      "Spectrophotometer   Spectrolino ; Serial number 12554"

MEASUREMENT_SOURCE   "Illumination=D50   ObserverAngle=2°        DensityStd=ANSI A
   WhiteBase=Abs   Filter=No"
ILLUMINANT           "D50"
OBSERVER             "2°"
FILTER_STATUS        "ANSI A"

PRINT_CONDITIONS     ""

NUMBER_OF_FIELDS     7
BEGIN_DATA_FORMAT
SAMPLE_ID       LAB_L   LAB_A   LAB_B   XYZ_X   XYZ_Y   XYZ_Z
END_DATA_FORMAT

NUMBER_OF_SETS       638

BEGIN_DATA
1        95.06   -0.29   -4.06   84.44   87.77   77.07
2        87.86    0.29   -5.27   69.32   71.78   64.57
3        81.79    0.18   -4.03   57.82   59.92   53.03
4        76.01    0.36   -2.99   48.23   49.91   43.52
5        69.77    0.02   -3.34   38.97   40.43   35.64
6        64.34   -0.15   -2.87   31.98   33.23   29.13
7        57.58    0.14   -3.17   24.63   25.52   22.66
8        52.62    0.45   -3.18   20.04   20.70   18.48
9        47.26    0.94   -3.47   15.79   16.22   14.69
10       41.21    1.24   -3.36   11.74   12.00   10.94
11       35.17    1.20   -2.86    8.41    8.58    7.79
12       29.76    1.14   -2.36    6.02    6.14    5.53

... ... ...

634      69.98   -0.20   -3.15   39.18   40.72   35.75
635      75.88    0.19   -2.70   47.97   49.70   43.11
636      81.68    0.12   -3.86   57.59   59.70   52.69
637      87.93    0.26   -5.13   69.44   71.93   64.55
638      95.00   -0.30   -3.96   84.29   87.62   76.82
END_DATA
```

Step C: Generate the printer calibration file.

This step will combine the known CIE Y input values (in the file `w11_calibration_cin.data`), that were used to generate the calibration test pattern, with the actual CIE Y values from the spectrophotometer measurements, and create a “calibration file” which maps desired Y values, to “calibrated Y values”—which is necessary to produce the desired values on print.

In the terminal window enter this:

```
w11macro.exe --mio ..\mio_setup\mio_step_c_calibration.txt
```

This uses the included demo files. If you wish to actually make a calibration for your printer using the measurements from step B, then you must change the file `mio_step_c_calibration.txt` so that it specifies those file names instead.

This demo uses five CIE Y data input files. Running the program should lead to output similar to this:

```
Creating calibration based on 5 data file(s).
Data file: ref__113405.it8
BEGIN_DATA found
reached END_DATA
Number of data points: 638 by 638
Data file: ref__114010.it8
BEGIN_DATA found
reached END_DATA
Number of data points: 1276 by 1276
Data file: ref__114733.it8
BEGIN_DATA found
reached END_DATA
Number of data points: 1914 by 1914
Data file: ref__122122.it8
BEGIN_DATA found
reached END_DATA
Number of data points: 2552 by 2552
Data file: ref__130445.it8
BEGIN_DATA found
reached END_DATA
Number of data points: 3190 by 3190
Testing calibration:
0 ===> 0.25
5 ===> 43.768
10 ===> 54.0255
15 ===> 60.1778
20 ===> 65.3892
25 ===> 70.0422
30 ===> 73.766
35 ===> 76.8798
40 ===> 79.8218
45 ===> 82.7145
50 ===> 85.3942
```

```
55 ===> 87.8661
60 ===> 90.2378
65 ===> 92.4795
70 ===> 94.4579
75 ===> 96.1721
80 ===> 97.7315
85 ===> 99.2165
90 ===> 100
95 ===> 100
100 ===> 100
Done.
```

Check the output from the program. The calibration file C:
`\w11macro\generated_calibrations\w11_calibration.cal` should have been generated. In the terminal window, you will see results from testing the calibration file, such as: `35 ===> 76.8798` which indicates that in order to obtain a printed value of Y=35, the input value 76.8798 * 255/100 must be written to the bitmap image.

Step D: Generate macro-uniformity ruler samples

This step generates images for the macro-uniformity ruler, including the 170 mm by 170 mm defect region and the test target surrounding the defect. Enter:

```
w11macro.exe --mio ..\mio_setup\mio_step_d_scale.txt
```

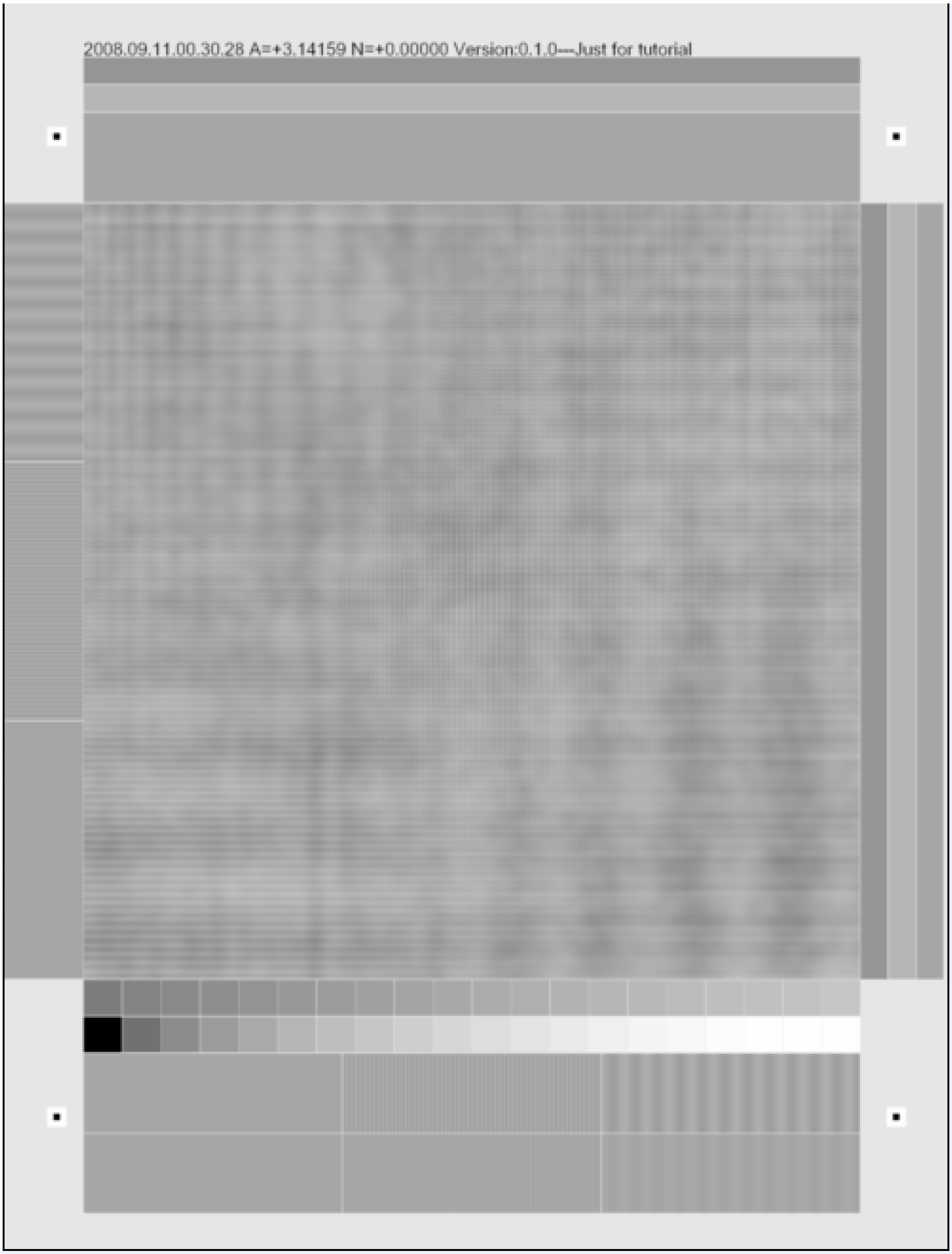
This uses a mio input file that specifies an overall amplitude of 3.141592 - just as an example. It may take a while to complete this command. The output will look like this:

```
Mottle          #1001...
Mottle          #1002...
Mottle          #1003...
BandingSweep            #2001
BandingSweep            #3001
RandomStreaks           #3002
BandingSweep            #5001
RandomStreaks           #5002
BandingSweep            #5003
BandingSweep            #6001
RandomStreaks           #6002
BandingSweep            #6003
BandingSweep            #4001
RandomStreaks           #4002
```

```
Defects completed
Rendering defects...
Minimum = 8.87311
Mean =    20.0084
Maximum = 33.8296
RMS =     3.14189
Applying calibration...
Wrote image <C:\w11macro\generated_scales\w11macro_scale_a=31415_n=0.bmp>
Dimensions: 2480 by 3295
```

Check that the scale image has been generated. It will be in C:`\w11macro\generated_scales` with name such as `w11macro_scale_a=31415_n=0.bmp` where n=0 indicates that no noise was added to the image.

Print the BMP file using same printer and settings as earlier. The image should appear as follows:


2008.09.11.00.30.28 A=+3.14159 N=+0.00000 Version:0.1.0---Just for tutorial

Generation of the entire macro-uniformity ruler

The ruler images are generated like as in step (D) of the previous section. The only difference is that different MIO input files are specified. All the files are included with the software distribution, and they differ only in the value of the `Amplitude` parameter. To generate all image files, enter:

```
w11macro.exe --mio ..\mio_scale\mio_a_0.000.txt
w11macro.exe --mio ..\mio_scale\mio_a_0.239.txt
w11macro.exe --mio ..\mio_scale\mio_a_0.357.txt
w11macro.exe --mio ..\mio_scale\mio_a_0.535.txt
w11macro.exe --mio ..\mio_scale\mio_a_0.802.txt
w11macro.exe --mio ..\mio_scale\mio_a_1.201.txt
w11macro.exe --mio ..\mio_scale\mio_a_1.799.txt
```

This will generate the 7 scale images.

The command-line interface (example 1)

The w11macro executable is run from the command-line by specifying an input file which contains all the remaining input parameters, for example:

```
w11macro.exe --mio ..\mio_setup\test1-mio-in.txt
```

The MIO input file

The input file to the `w11macro` program is called a *MIO-file* (for *Macro-uniformity Input Output*). This provides a very simple way of specifying input parameters for the program. The fastest way to understand how to use the MIO file is by example. Here is the contents of the MIO file `C:\w11macro\mio_setup\test1-mio-in.txt`:

```
UUID:2009-09-14
IMAGE:images/t1.tif
TIME:2009.09.14.12.35.10
EXMID:simulation
STATUS:0
INPUTS:20
SS::Directory::C:\w11macro
DS::Mean::50.000000
DS::Amplitude::3.000000
DS::Noise::10.000000
SS::Label::Test of MIO
SA::CIELabFiles::2
ref__113405.it8
ref__114010.it8
FA::VerticalBandsFrequencies::2::0.5 0.05   EOA
FA::VerticalBandsAmplitudes::2::0.5 0.05    EOA
FA::HorizontalBandsFrequencies::0::         EOA
FA::HorizontalBandsAmplitudes::0::          EOA
FA::MottleLowFrequencies::0::               EOA
FA::MottleHighFrequencies::0::              EOA
FA::MottleAmplitudes::0::                   EOA
FA::VerticalIsolatedStreakLocations::0::    EOA
FA::VerticalIsolatedStreakWidths::0::       EOA
FA::VerticalIsolatedStreakAmplitudes::0::   EOA
DS::VerticalRandomStreakAmplitude::0.000000
DS::VerticalRandomStreakMinimumPeriod::0.000000
DS::VerticalRandomStreakMaximumPeriod::0.000000
SS::Filename::w11_simulation.tif
OUTPUTS:2
00::MeasuredAmplitude::<<unknown_type>>
00::MeasuredFrequency::<<unknown_type>>
END
```

The text is marked up as follows:

- Blue: MIO keywords.
- Red: Parameter names defined and used by the w11macro program.
- Green: Parameter values that you specify in order to control the w11macro program.

Lines 1 through 5 must always appear in the MIO file:

- UUID: Any identifier you wish to associate with this file. It is not currently used.
- IMAGE: The path to an input image file, in cases where the program is being used to analyze an existing image (for compliance with scale specifications).
- TIME: Is not currently being used.
- EXMID: Is a string that specifies which function the program should perform. The currently acceptable values are:
    - `analysis`: Intended for analysis of specification compliance, but not yet supported.
    - `scale`: Create scale images.
    - `calibration`:
    - `tp_calibration`: Create a bitmap file for the calibration test pattern.
    - `simulation`: Create image with simulated defects, according to parameters specified in the MIO file.
- STATUS: The value should be 0. When the program has completed, the value may be changed to indicate success or failure of the program.

The remainder of the file has two sections, the INPUTS section (lines 6 through 28) and the OUTPUTS section (lines 29 through 32).

Line 6 “INPUTS” specifies the number of input parameters that follow in the subsequent lines. In this case there are 20 input parameters. Lines 7 through 28 specify the names and values of these 20 input parameters (some are lists with more than one scalar value). MIO supports just a few different parameter types, coded as follows at the beginning of each line:

MIO 2-character keyword	C++ data type	Comments
SS	string	A single string of text that extends to the end of the line.

MIO 2-character keyword	C++ data type	Comments
LS	long integer	A single integer.
FS	float	A single 4-byte floating point number.
DS	double	A single 8-byte floating point number.
SA	list of string	For example the “CIELabFiles” parameter. The first number specifies how many strings are in the list. Each string in the list must appear on a separate subsequent line.
FA	list of float	For example the “VerticalBandsFrequencies” parameter. The first number specifies how many values are in the list. Each value must appear on the same line separated by spaces. The last value must be followed by space and the characters “EOA”.

The purpose of the output section of the MIO file is to request that certain calculated values are placed into the MIO file when the program is executed. This can be useful both for obtaining intermediate results, and to obtain the results of image analyses for scale sample compliance testing. The output section starts (at line 29) with the OUTPUTS keyword, and specifies how many output parameters are requested. This is followed by one line for each requested output parameter. Only the name of the output parameter is given, using the format:

00::*parametername*::<<unknown_type>>

where *parametername* is some known name of an output parameter that is provided by the w11macro program. Upon completion of the program the actual two-character code for the parameter type, and the parameter value will be filled in, using the same format as for the input section.

The output section (and the MIO file) is terminated by a line with the keyword “END”.

Input parameters

Parameter Name	Type	Description
Directory	SS	The full path to the w11macro directory.
Mean	DS	Mean Y value (0 - 100)
Amplitude	DS	Overall defect amplitude for scale generation.
Noise	DS	Amplitude of noise.
Label	SS	Label that will be placed on teh generated image (for example parameter values).
CIELabFiles	SA	A list of 1 or more filenames, for files that contain CIELab data for calibration. More than one file can be provided in order to reduce the impact of measurement noise. The files must be located in the calibration_input folder.
VerticalBandsFrequencies	FA	A list of frequencies (c/mm) for vertical bands.
VerticalBandsAmplitudes	FA	A list of amplitudes (Y) of vertical bands (must be in the same order as the list of frequencies).
HorizontalBandsFrequencies	FA	A list of frequencies (c/mm) for horizontal bands.
HorizontalBandsAmplitudes	FA	A list of amplitudes (Y) of horizontal bands (must be in the same order as the list of frequencies).
MottleLowFrequencies	FA	List of lower frequency range for mottle defects.
MottleHighFrequencies	FA	List of upper frequency range for mottle defects.

Parameter Name	Type	Description
MottleAmplitudes	FA	List of amplitudes for mottle defects.
VerticalIsolatedStreakLocations	FA	List of locations of vertical isolated streaks.
VerticalIsolatedStreakWidths	FA	List of widths (mm) of vertical isolated streaks.
VerticalIsolatedStreakAmplitudes	FA	List of amplitudes of vertical isolated streaks.
VerticalRandomStreakAmplitude	DS	Amplitude for random streaks.
VerticalRandomStreakMinimumPeriod	DS	Minimum period for random streaks.
VerticalRandomStreakMaximumPeriod	DS	Maximum period for random streaks.
Filename	SS	File name of the generated output image.

Creation of simulated defects (example 2)

The w11macro program can create images with simulated defects. The images are used by the proposed standard in order to test application of the macro-uniformity ruler to typical printer defects. Enter:

```
w11macro.exe --mio ..\mio_setup\mio_example_2.txt
```

```
I:\w11dist\w11macro-0.1.2\apps>w11macro.exe -d I:
\w11dist\w11macro-0.1.2\testdirectory -m simulation --sim_v_bands (0.1,2.5)
--sim_h_bands (0.2,1.0) --sim_mottle (3,6,4.0)

Creating simulated defects
Added defect: Banding: A=2.5 Lambda=10 Phase=0 Direction=Vertical
Added defect: Banding: A=1 Lambda=5 Phase=0 Direction=Horizontal
Added defect: Mottle: A=4 Periods from 3 to 6 mm
Generated simulated image: I:
\w11dist\w11macro-0.1.2\testdirectory\generated_scales\w11_simulation.bmp
Dimensions: 2480 by 3295
Done.

I:\w11dist\w11macro-0.1.2\apps>
```

The image should look like this:

2008.10.08.16.46.27---_no_label_

Document history

Version	Date	Author	Comments
0.1.0		D. René Rasmussen	Initial version.
0.2.0	2010-01-08	D. René Rasmussen	Updated for new command line interface.
0.3.0	2018-04-02	D. René Rasmussen	Updated for version that uses BMP image format rather than TIFF.