Automatic Mechanical-Band Perceptual Evaluation

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Abstract

Singular mechanical bands may come in a variety of width, shapes, intensity and neighborhoods. Those bands are non-periodical, appear across the sheet (from side to side), and are often wider than 2mm, which makes them noticeable from a normal viewing distance. Massive manual evaluation of mechanical bands is done during the development of new printers, in order to remove the mechanical cause of the bands, and during Print Quality (PQ) tests. In some cases, as in monitoring improvements following a test of a proposed solution, or in the press-release quality tests, the test should be objective and repeatable, qualities that do not exist in human observations. An automatic tool for perceptual evaluation of mechanical bands is, hence, preferable.

In this paper, we steady human priorities in singular band evaluation. In particular, we find the human sensitivity function per band width of singular bands, which differs from the well-known human sensitivity function to wave- length of periodical bands. A main result of our steady is a Mechanical Band Measurement (MBM) tool. The MBM tool rates general mechanical bands in a score that correlates with band severity. We compare the tool's scores to committee evaluations and show that the tools agreement with the committee is better than the agreement between the members of the committee.

Work process

The MBM tool is a scanner based processing tool, which replaces the labor of the experts who are currently evaluating the bands. Using the tool one has to print a test job (gray patch in Figure 1) and scan it. The MBM tool reads the scanned images in the input directory one after the other, register them so that the mechanical bands are parallel to the image edge, and calculates the orthogonal profile. Next, the orthogonal profiles are analyzed, as explained in the following sections.

Challenges

The first, most important challenge, is Determining which of the band's features influence human ranking, and how. Perceptual band severity is defined by human observers, who sub-consciously capture the many features of the band, and compare them. Due to the sub-conscious and subjective nature of band evaluation, identifying those priorities is a non-trivial task. Figure 2 demonstrates the complexity of this task. The figure shows the profiles of two bands with seemingly equivalent severity: Half of the human observers rated band K (the profile of it's scan is shown in Figure 2 top) as more noticeable than band H (lower), and the other half ranked them in the opposite way. While the severity of those bands is equivalent, their features seems to have nothing in common: Band K is wide and isolated, while band H is thin and surrounded by other bands. It is the combination of the different features makes those bands equivalent.

The second challenge is to identify bands, and define their exact boundaries. While this task appears to be simple, we found it very hard, both manually and automatically. Some bands that look separated in close examination appear as one band from a more distant view. Other bands have vague boundaries. Upper part of Figure 3 brings the results of an experiment in which eight experts where asked to mark the bands on a page (which is brought as back-ground). The variability in the marked band-locations is so big, that without additional knowledge it would be hard to guess that they all refer to the same sheet.

Last challenge is that the influence of neighboring bands on the perceptual evaluation of a given band is not clear. On one hand, other bands can mask the severity of the evaluated band, and on the other hand, the opposite bands between each two bands create a sharpening effect.

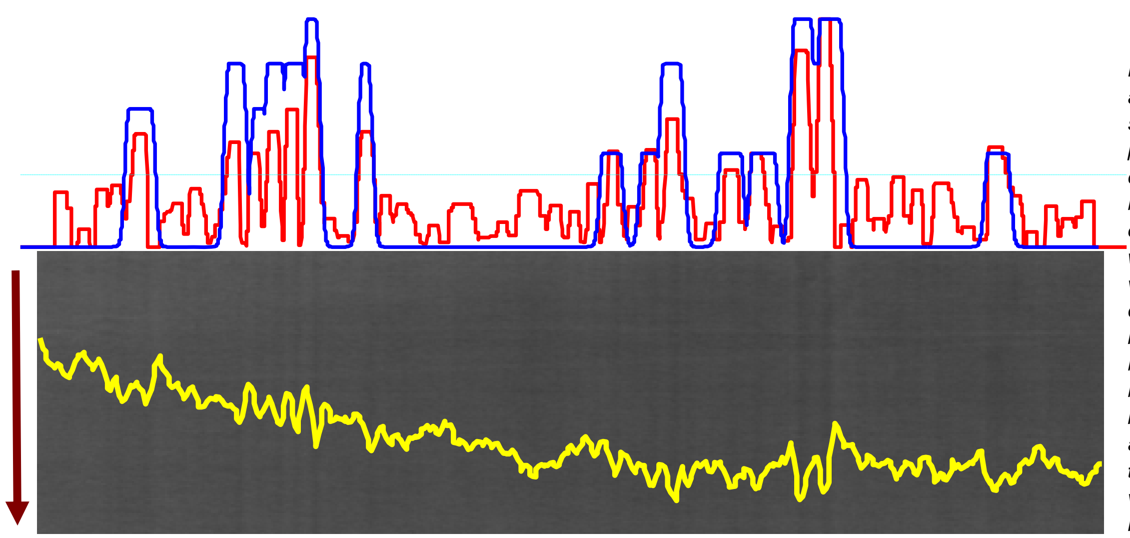

Figure 1. The gray patch is an exaggerated scan of a sheet printed in an Indigo press, where the vertical dark lines are mechanical bands. Yellow is the profile of the scanned sheet, which is the mean gray value, averaged over band direction (brown arrow, left). Blue line indicates the band visibility as marked by a human observer. Red line indicates band visibility as measured by the MBM tool. Cyne line separate visible band level from noise.

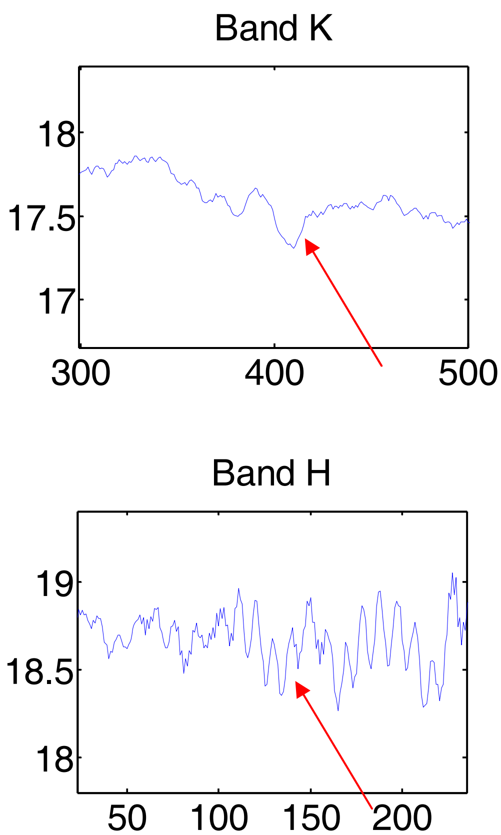

Figure 2: Profiles of scans of two bands, band K and band H. The two bands differ in scale, neighborhood amplitude and shape. The two bands were pair wise equivalents in Human evaluations

Our solution and prior art

While harmonic bands were intensively investigated (see, for example, [1]), singular mechanical bands were less researched. Some aspects of evaluation of mechanical bands are similar to aspects in general artifact evaluation (known as image fidelity), but since mechanical singular bands are spread in a straight line across a page they have a unique salient presence, especially in smooth print sections such as graphics or blue sky patches. However, we did start our research with image fidelity approaches, as they face challenges that resemble ours. Many fidelity approaches are based on the human visual models in the frequency domain (MTF), originally extracted for harmonic bands. Other works use similar models, were the sinusoidal basis of the frequency domain is replaced by Gabor basis [2,3] or alternative basis [4,5], but the weights of the different basis are determined according to an MTF function, or extracted from small scope tests. Additional approach is based on matched filter, were the correlation between the artifact and image is calculated [6]. In the case of a well-localized band artifact with characteristic width, we found that all approaches amount to the derivative of a Gaussian whose width corresponds to the typical band artifact width. Since in the general case the width of the bands varies, we generalized our approach to a series of convolutions with derivatives of a set of Gaussians, with a variety of widths. The resulting structure is known in the literature as scale space. Scale spaces have some interesting mathematical phenomena. Some of those phenomena are demonstrated in Figure 4, which shows the log of the local maximum of convolutions in sequential scales. Bands appear in a different scale (left) and split into several bands when moving to the finer scales (right). In our perceptual band measurement problem, the different scales can be compared to viewing the bands from different viewing distances, where the shorter the viewing distance the more bands one can see.

Analysis

We start by extracting two multi-scale spaces, one for light bands and one for dark bands. We do that by convolving the profile of the image (e.g. yellow line in Figure 1) with a kernel, which is the derivative of a gaussian, shown in Figure 6, in several scales. There are three flavors of the tool, one that looks for dark bands, another looks for light bands, and the third that looks for both. If the both option is on, we combine the two scale-spaces into one, by taking the maximal of the two responses in each scale-position location. Other wise, only the relevant Multi-scale space is considered. Responses to a given band appear in many scales;

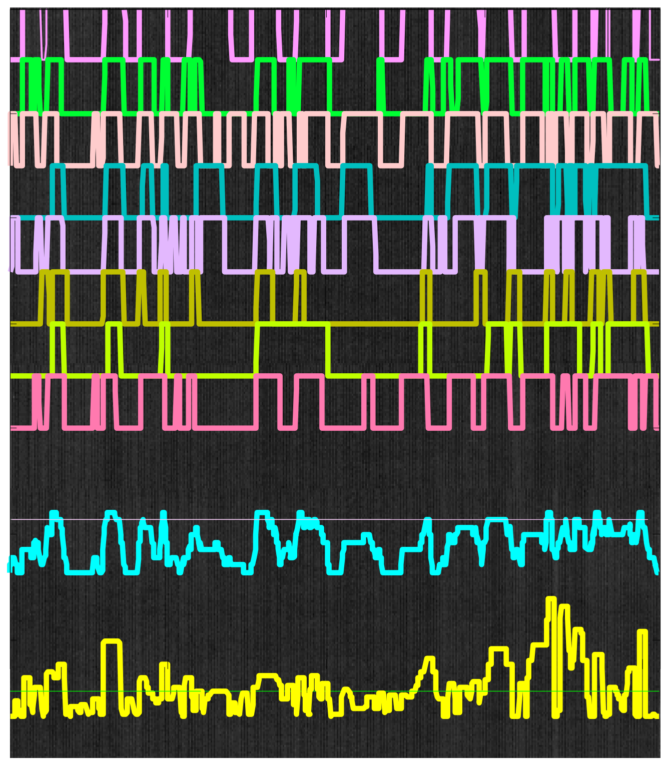

Figure 3: Top: *Eight experts evaluate the bands on a given sheet, scanned at the background of the image. The correlation between the band-definitions of the evaluators is loose.*
Bottom: *Cyne line is the number of evaluators who identified a band in each location. Pink line marks seven evaluators, hence in regions where the cyne line is above the white line there is agreement that this is a band. Yellow line below is the severity of the band as evaluated by the proposed MBM tool. Using the threshold marked by the green line, the MBM tool identified all of the bands noted by seven or more evaluators.*

hence, we trace the position of the band and group the features that describe it. Human responses depend of the characteristic width of the band, hence we multiply the features by the weight of the scale they relate to. Those scale-weights yield the human sensitivity function for singular bands, brought in Figure 4 right. In developing this function, we started from the well-known human sensitivity function for frequencies, where we replaced the wave-length of the repeating bands with the band-width of the singular bands. The resulting function did not match human evaluation of singular bands, hence we farther changed it to match human band-severity evaluation over a large set of printed training sheets.

After multiplying the features by the weights of their scale, we take the maximal weighted feature that describes each band to represent this band. Last, neighboring bands are taken into account, and we compensate for the reduction in convolution values that result from the existence of the neighboring band.

MBM output

The red line in Figure 1 illustrates MBM results. The results are numbers that describe the severity of the band that might exist in each location along the print. Those numbers are relative, and not absolute: Applying any monotonic function on the marks extracted by the tool is valid, since the numbers themselves are meaning less, and it is only the comparison between the marks extracted by the tool to two different bands, which indicate their relative severity. Comparing the MBM results to the human evaluation of the same print (blue line) one can see that

a. There is an overall agreement between the relative marks given to the bands by the tool, to the relative marks given to the bands by the human evaluator. For example, the three bands which are evaluated as worth (highest values) by the human evaluator are also evaluated worth by the tool, though the tool distinguish between them and rate one of them as the worth and the other two as second worth.

b. There is a threshold, plotted as a cyne line in Figure 1, that distinguish the marks given by the tool to real marks, observed by the human evaluator, to noise.

The results brought in Figure 1 are typical to the output obtained for many tested sheets. However, it takes an independent, well designed perceptual test to verify the tool. The perceptual test preformed for the MBM tool is described in the next section.

Perceptual Test

The test contains 17 bands that represent the variety of bands in the indigo presses. The 17 bands are printed in eight sheets, where some of the sheets contain more than one band, up to four bands per sheet. The tool developers were not exposed to the selected sheets prior to the test. Thirty human observers volunteered to take part in the test, all of them experienced in mechanical bands evaluation in Indigo. During the test, each of the thirty observers ranked the bands from "1" (the least disturbing band) to "17" (most disturbing band). The ranking was done in normal work environment conditions. We denote the union of those ranks as committee votes.

Given committee votes and any additional rank, we can evaluate the additional rank with a Rank Agreement Measures (RAM) that measures the agreement between this rank and the committee votes. The RAM we use is the means Spearman rank correlation [7]. We attache a RAM to each of the observer's ranks, as describe by red dots in Figure 5. The red line denotes the mean of the observer's ranks. The Borda rank is the best theoretical match to the committee, and it's RAM is denoted by blue line. We then apply the MBM tool on a scan of each sheet, and extract the MBM marks given to each of the seventeen bands. By ordering those marks, we obtain the MBM rank. The RAM of the MBM rank is denoted by a magenta circle in Figure 5. Notice that he RAM of the MBM rank is close to the maximal possible value. More important, the RAM of the MBM rank is higher than the mean observer's RAM, which means that the MBM tool describes committee ranks better than the mean human observer does.

Identification Test

In order to verify that all of the bands in the page are detected, with no false detections, the following test was constructed. Eight expert observers got four printed sheets, with a ruler attached to each of the printed sheets. Each of the experts marked the location of the bands on the page. The position marked by the human evaluators where collected, as demonstrated in Figure 3. The number of evaluators that noticed a band in each location was calculated (cyne line in Figure 3 low). We listed all of the locations were seven or eight observers marked band (above the thin pink line on the cyne line in Figure 3 low), a total of 30 bands. Next, we determine a threshold of 0.12 on the MBM value.

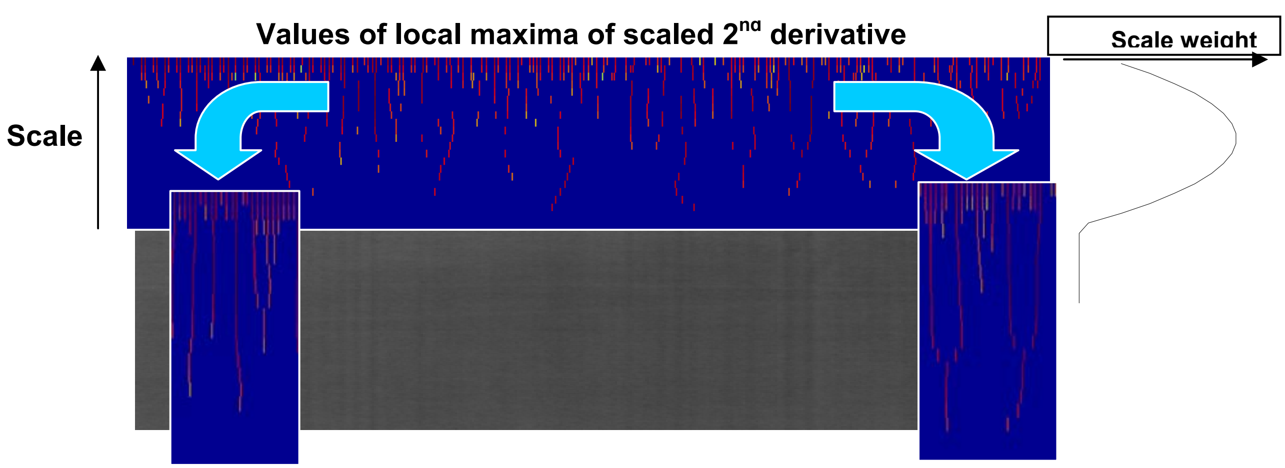

Figure 4. *Multiscale space of the profile of the gray image (low). We multiplay the resalts in each scale by a weight function (right) to find the scale that corrisponds to each specific band. The weight function on the right describes humnan sensitivity as fucntion of the width of the bands in each scale.*

The threshold was set so that all of the bands noticed by seven or eight observers have MBM values higher than this threshold.

Out of the thirty bands marked by seven or more observers, 28 bands where detected by the MBM, set to find dark bands. One other band is a light band, which is detected when we set the MBM find light bands. The last band does not appeared on the entire sheet, but only on part of the sheet, hence does not match the definitions of the MBM tool. On the other side of the confusion matrix, 47 of the 48 bands marked as such by the MBM where noticed by 4 people or more, and the last one was marked by 3.5 observers, i.e. was close to the edges of the marked bands.

Conclusions

In this paper, we presented the Mechanical Band Meter (MBM) tool. The MBM accepts a scan of a gray test job as input, and attach each location along the page with an MBM mark, which is a number that estimates the severity of a possible band in this location. We show that the MBM mark agrees with the mean human evaluation of the severity of the band in each location. We farther showed that the MBM tool finds the significant bands on the printed page.

References

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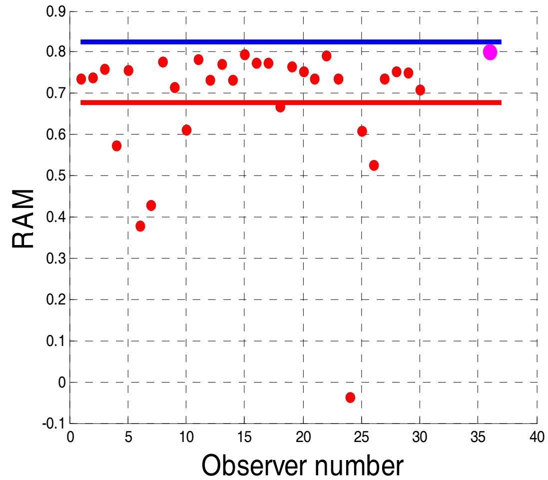

Figure 5: *Test results. The Per-page band meter (pink dot) describes committee votes better than the mean human observer does (red line).*

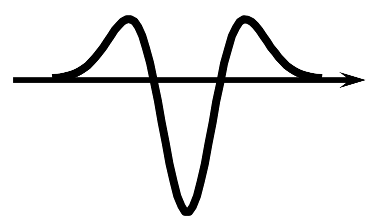

Figure 6. *The the derivative of a Gaussian was shown to give good preceptual evaluation in the case of a well localized band with charecteristic width.*