Supplemental Material: Watercolor woodblock printing with image analysis

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Abstract

This document consists of additional material for the submitted paper "Watercolor woodblock printing with image analysis". It presents details of the "shading woodblocks" algorithm, our decisions on the fabrication pipeline. Also, it contains the output of the image analysis pipeline and lasercutter input for our final prints. To make easier comparable photographs we match their colors using Adobe Illustrator.

CCS Concepts

*●**Human-centered computing** → **Interface design prototyping;** ●**Computing methodologies** → Image processing; Image representations; ●**Applied computing** → Fine arts;*

1. Water woodblocks

To build the shadow block corresponding to a color region, we proceed as follows:

1. Compute superpixels, sets of neighboring pixels in the grayscale map image that have the same gray intensity value. Next, Process every color region of the color map separately.
2. Initialize the set of shadow superpixels with the locally darkest superpixels, are all the superpixels that all their neighbors have paler or equal intensity values.
3. Build the set of candidate superpixels as the superpixels not selected yet with brightness less than 1.1 of the brightness of the color region.
4. Define a graph over the superpixels as following: Every superpixel represents a node in the graph. There is an edge between any two nodes iff the corresponding superpixels have at least one neighboring pixel. The edges are weighted with the difference of the brightness values between the two superpixels.
5. Expand the shadow superpixels to the closest neighbor superpixel in the graph. Update the graph by merging the two nodes. Update the edges and their corresponding weights, according to the brightest value of all the superpixels included in the expanded superpixel.
6. For every superpixel if there is no candidate or if the number of pixels of the superpixel is greater or equal to 20 pixels, stop expanding.

To remove small details, we perform a series of morphological operations on the images with a disk of specified radius. The radius r is used to define a disk of total size $2 \times r + 1$ in OpenCV. Given that all our images are of size 800 pixels × 600 pixels, 1 pixel radius corresponds to approximately 0.25 mm radius.

We smooth the input image with an open followed by a close operation of radius 0.25 mm. For the darkest superpixels (Wet Woodblocks - Shading Woodblocks - Local Minima) to compute the grayscale map we use k-means for $k = 30$ grey values on the greyscale input photograph. We then smooth the image with an open followed by a close operation of radius 0.5 mm. We shrink the water area of the water map with an erode operation of radius 0.25 mm and we remove the dry area. To compute the grayscale map for the details superpixels (Dry Woodblocks - Details minima) and the brightest superpixels (Wet Woodblocks - Shading Woodblocks - Local maxima), we use k-means for $k = 50$ gray values. We smooth the grayscale map with a close operation of radius 0.25 mm. We process all the colors together, differently than algorithm's Step 1. For the brightest superpixels, we consider the local maxima, which have color values greater than 220 (gray channel $\in [0, 255]$), Steps 2 - 3. Also, we do not expand, eliminating Steps 4-6.

2. Masking the paper

The paper needs to withstand heavy dampening with water without tearing apart, to allow for the diffusion of the colors and to permit some kind of masking technique. In order to meet our low budget objective, we experimented by using conventional papers for printing and cheap watercolor papers. These papers were not suitable for our fabrication pipeline. Specifically, some paper types diffuse color more easily than watercolor paper, but they are destroyed when we apply masking or water. We use Arches hot pressed paper $300 \, \text{g/m}^2$ which met all the above criteria.

For masking the paper, we experimented with ideas borrowed

from watercolor painting. We used different leveling on the woodblocks that could simulate the touch or non touch of a brush on the paper, but all of the outcomes resulted in failures. Thus, we looked into how we could combine masking fluid or tapes and stencils.

All of the tapes and stencils we tried seemed to visually disturb the surface of our paper. To cut the tape or the stencil to a desired shape, we used a vinyl cutter. The benefit of this technique is that the resulting masking area has a very sharp and accurate shape. A negative is that the exact

Figure 1: Choosing materials for masking. On the left we applied masking fluid which we removed. On the right we experimented with stencil & tapes.

alignment of the stencils/tapes on the printing in progress becomes complicated. Also, we had to manually remove the negative areas of the stencils/tapes once glued on the paper. This process becomes more difficult when the complexity of the shape of the masked area and the number of the disconnected pieces of the shape increases.
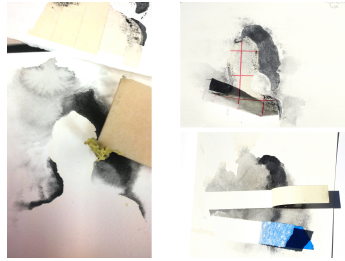
For all the reasons mentioned above, we decided to use masking fluid. Compared to the tapes, the masking fluid disrupts the paper less. We confirmed that we can apply the masking fluid using a regular woodblock. Therefore, deviations from our printing process were not necessary. We brush it and press the woodblock on the paper three consecutive times. However the masking fluid creates shapes which are less sharp-accurate, compared to the shapes created by the stencils. The masking fluid is always applied on the white paper before application of other colors and is removed after it dries using rubber cement.

3. Carving the blocks

Our goal was to create multiple prints from the same woodblocks. In other words, we wanted the woodblocks to withstand the pressure from the machine press without tearing apart. Also, we wanted the carved area of the woodblocks to be as close as possible to the black-white images given as input to the machine. For that reason we first looked into a variety of machinery to carve the woodblocks. We tried two laser cutters Laser Pro Spirit GLS, C180II and a CNC (computer numerical control) milling machine, ShopBot Desktop. The woodblocks carved by the milling machine were not as detailed as the woodblocks carved by the laser-cutter. Specifically in Figure 2, one can see three woodblocks and their corresponding prints on the right. The first two, Figures 2a, 2b, were carved by the milling machine, while the third, Figure 2c, by the laser cutter. Many of the small areas that were correctly carved by the laser-cutter were destroyed by the milling machine, which is evident on the prints. To successfully print an image from a woodblock carved by the milling machine, we substantially thickened the lines of the block Figure 2b. Therefore, the milling machine is not appropriate for our small scaled woodblock printing.
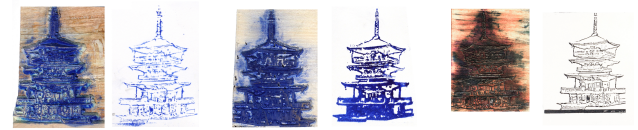
(a) Unsuccessful print, carved by milling machine

(b) Successful print by milling machine thickening the lines

(c) Successful print, carved by laser-cutter

Figure 2: Woodblocks carved by different machines and the prints produced by them
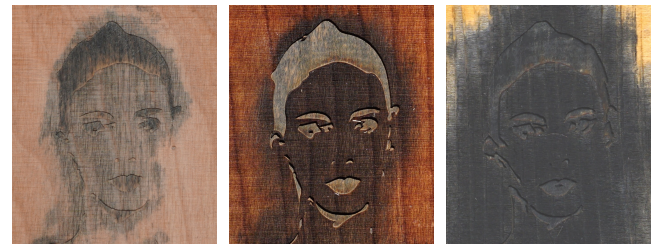
(a) Plywood (b) Cherry (c) Pine

Figure 4: Carving different types of woods

We chose the Laser Pro Spirit for all the reasons mentioned above and because the smaller laser-cutter C180II was slower and could not cut through our 13 mm thick woodblocks.

The time to carve one plywood woodblock of size $200\,\text{mm} \times 150\,\text{mm} \times 13\,\text{mm}$ using the Laser Pro Spirit GLS, was approximately 20 min, depending on the input image.

Small elevated pieces in the woodblock are very easy to break with multiple prints. To address this issue we explored multiple materials.

Specifically, in Figure 3 there are two prints of the same image. The laser cutter carved the image onto a woodblock and on a Plexiglas block. The print resulting from the woodblock is placed on the left of the Figure, while the print from the Plexiglas block is placed on the right of the Figure. Plexiglas produced a low quality print with watercolors. We also tried MDF (Medium-density fiberboard), which also gave bad quality prints. Therefore, we rejected them.
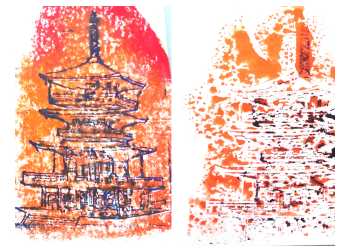

Figure 3: Prints by blocks carved on different materials: woodblock Vs Plexiglas block

We tested pine (Figure 4c), cherry (Figure 4b) and plywood (Figure 4a) and compared their results. Cherry gave strong woodblocks with sharp details but it was expensive compared to pine and plywood. The pine wood appeared to be the softest, and to be de-

stroyed easier after burnt by the laser cutter. Therefore we settled for plywood, which although less strong than the cherry, it was also more affordable. We could not print features thinner than 0.7 mm because the wood broke. For that reason for the details blocks we used the offset path tool of Adobe Illustrator with value 0.2 mm. We tried 0.6 mm thick plywood, but we noticed that the surface warped. The prints were not very good, because the pressure was not uniform on the entire surface of the block. We switched to 0.13 mm thick plywood, which in the majority of the cases remained flat. To avoid warping of the low thickness plywood, waterproofing could be effective.

4. Dampening the paper

Figure 5: Color expansion when dampening paper with brushes, the color gradients are not sufficiently big.

We want a substantial uniform water application to successfully print predictable water-color diffusion. We explored two methods for dampening the surface of the paper: brushing and spraying. For the brush watering experiments we used two different sizes of flat watercolor brushes, one of size 19 mm (Neptune Watercolor 4750 Aquarelle 75) and one of size 38 mm (Neptune Watercolor 4750 Mottler 150). We covered the paper with multiple parallel strokes one after the other. It became difficult to have uniform dampening of the paper because of strokes overlapped. Also, due to the time difference between the first and the last brush stroke, the paper dampening was inconsistent. Moreover, the control of the dampening was very dependent on the person that was doing it, and for that reason the amount of water was difficult to be measured. In addition the diffusion was not very big, to distinguish between the two different brushes we used different colors in Figure 5. The yellow represents the small brush and the black the big brush. The size of the expansion was approximately 0.1 cm for the small brush and 0.2 cm for the large brush (Figure 5).

Figure 6: Results of diffusion with excessive water application.

For all the reasons mentioned above we switched in using a spray which gave us better results. If we sprayed from a fixed position, we could not succeed in a uniform and fully covering the paper water application. Therefore, we moved around the spray trying to succeed an approximately uniform dampening. Here we noticed that if the spray sprays too fast or if it creates big droplets, it is

difficult for a person to maintain a uniform spray. We tried different sprays and the spray that gave the most satisfying results was a hand pump aerosol spray. The uniformity of the manual spraying using this spray was sufficient for the purposes of our fabrication goal. To have a more accurate and uniform liquid deposition we could use a patented technique [Wat94, RCJ*98]

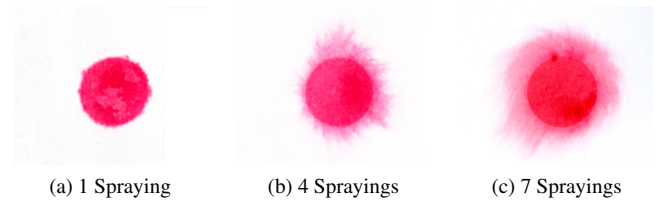
(a) 1 Spraying   (b) 4 Sprayings   (c) 7 Sprayings

Figure 7: Different number of spraying after the printing of the block

Finding a balance between the desirable abstraction and the undesirable uncontrollability of the watercolors was a main challenge of our work. Small water presence removed the abstract watercolor quality of the print, while excessive water gave unpredictable results (Figure 6). We looked into how we could controllably expand the area of color diffusion. When spraying happened before the printing, it resulted in big uncontrollable diffusions. When the paper is very wet, it adheres to the woodblock. Subsequently, the woodblock's removal from the paper is not smooth and it disturbs the water and the paints on the paper. On the other hand, if the surface is not wet enough, then the diffusion of the colors is small. To solve this problem, we apply the water in small quantities until we ensure the paper is uniformly and sufficiently wet. We then print the woodblock and finally we spray again to drive a wide controllable diffusion. The amount of this last spray influences the width of diffusion. The sub-figures of Figure 7 show the color expansion after 1 spray, 4 sprays and 7 sprays. The prints made with the same woodblocks, but by applying different amounts of water are in Figure 8. On the left the image sprayed with less water, at the right an image with our spray setting.

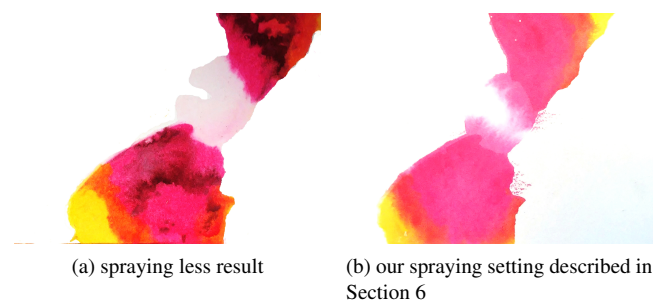(a) spraying less result   (b) our spraying setting described in Section 6

Figure 8: The same woodblocks for pink and yellow colors printed with different amount of spraying. Here, we adjusted the images to better match the input photo.

Figure 9: Result in diffusion by not well stretched watercolor.

5. Stretching the paper

To have uniform color diffusion we want the paper to be well stretched and attached to a plywood of 13 mm thickness. On Figure 9 is a not well stretched paper and the colors diffuse in an unpredictable way. Before the plywood, we had used boards specifically designed for stretching watercolor papers, but after a couple of iterations inside the machine press, the boards were destroyed. To stretch the paper we used a stapler which we found more successful than gummed tape. Sometimes it happened that even after we had stretched the paper it did not remain stretched when we wet it. In those cases we wet on the opposite side of the print and re-stapled the paper before we continued printing. To align the woodblocks we designed and assembled a corner using the laser-cutter. Please watch accompanying video to see the printing process and tools used.

In our fabrication process we use wet-on-wet to print the colors in both wet and dry areas. For the dry area the paper is moderately wet, as in traditional woodblock printing. For the wet area the paper is more wet and we apply additional water after the print. When we print the masking fluid we use wet-on-dry.

6. Changes in the image analysis pipeline

If the user does not want to have white lines, she can segment manually the woodblocks. We tried that for the flower, the corresponding printing is placed in Figure 10a.
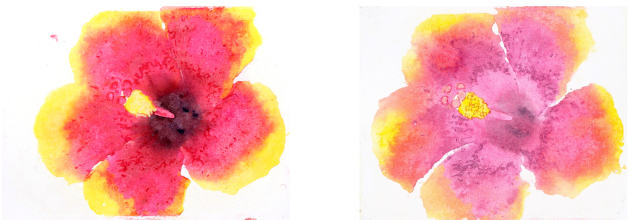
(a) Printing without leaving white areas on the edges.

(b) Printing by finding minima in the entire image.

Figure 10: Different approaches than ours. It's a matter of personal taste which is preferable.

Another idea that we looked into, was to create the blocks for local minima found on the entire image and not found in every color separately, similar to how we found the local maxima. One can look the resulting print when we changed the minima pink block for the Hibiscus flower in Figure 10b. The comparison to our decision of the minima block is up to the aesthetic interpretation of the designer.

Figure 11: Adding lines at places we now print masking fluid.

Some of the ideas we experimented with created prints with "reduced" watercolor look. We removed the gaps from the masking fluid by adding lines in places where white lines would be present Figure 11. While others placed the prints closer to the look of a traditional woodblock print, one such example is placed in Figure 12, this example has edges printed on the wet area.
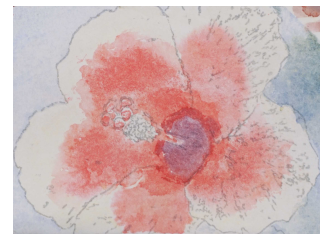

Figure 12: Adding eastern style lines, produces a less watercolor look.

References

[RCJ*98] REEVES B., CRAWFORD C., JONES B., ROUSSEAU G., WRIGHT J.: Removable applicator assembly for applying a liquid layer, Sept. 15 1998. US Patent 5,808,645. URL: https://www.google.com/patents/US5808645. 3
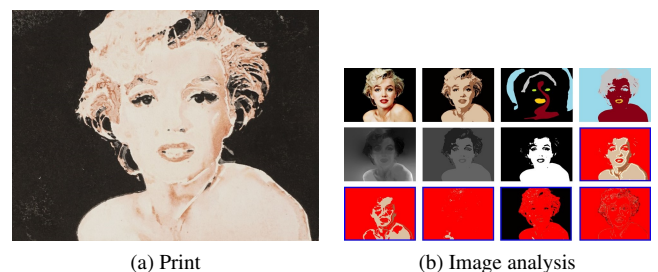

(a) Print

(b) Image analysis

Figure 13: Marilyn's Monroe portrait.

(a) Print   (b) Image analysis

Figure 14: The flower.

(a) Print   (b) Image analysis
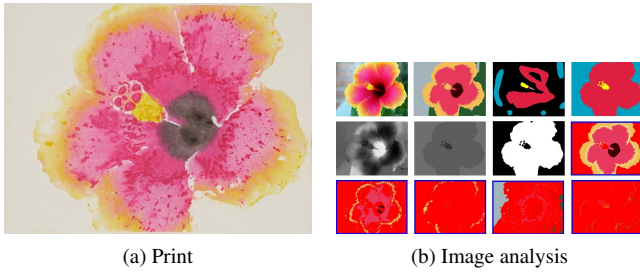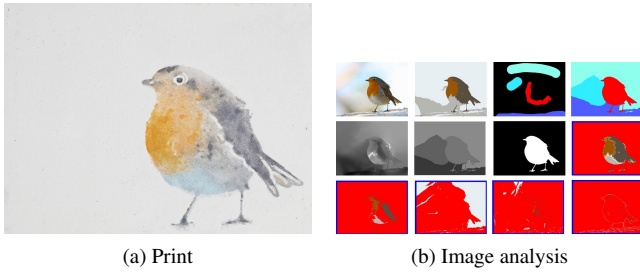
Figure 15: The Robin bird.

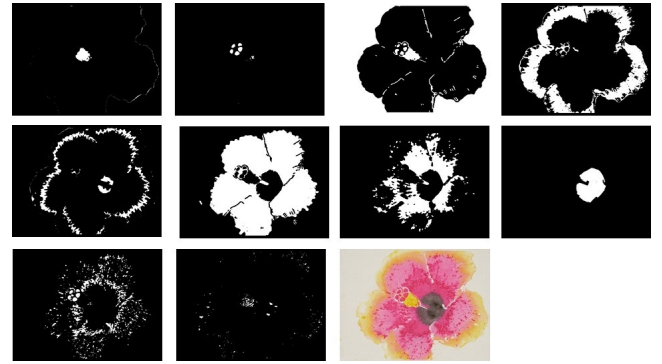[Wat94] WATT K.: Method and apparatus for applying thin coatings of fluid droplets, May 24 1994. US Patent 5,314,119. URL: https://www.google.com/patents/US5314119. 3

Figure 17: The blocks for the Hibiscus flower.
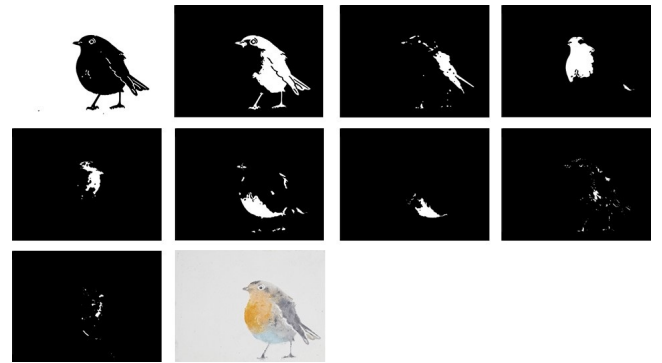
Figure 18: The blocks for the Robin bird.

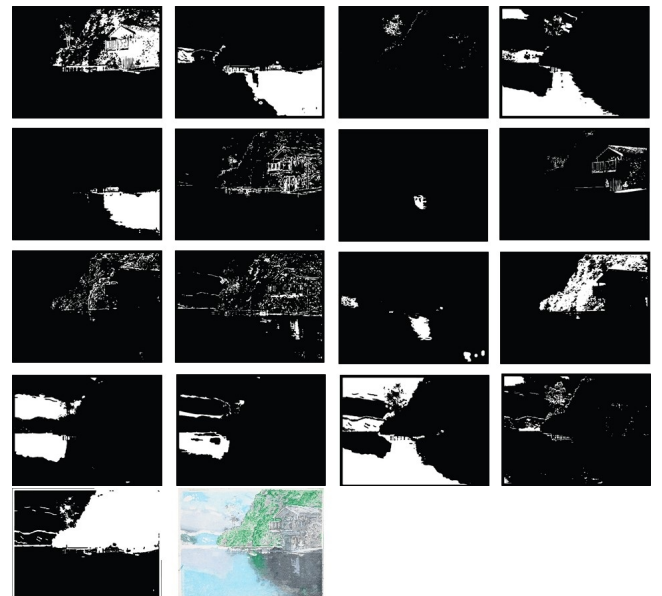Figure 19: The blocks for the house on the lake.

(a) Print   (b) Image analysis
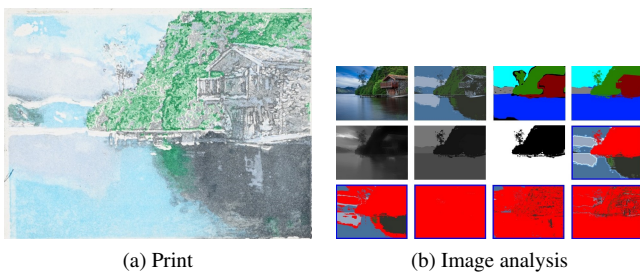
Figure 16: The house on the lake.