High Quality Offset Printing – An Evolutionary Approach

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ABSTRACT
Print media are still very important for everyone's daily life. Current efforts are concerned with the application of the well-established offset-printing technology to other media, particularly cardboards, which require some substantial adaptations. To this end, this paper proposed a new specific pre-processing stage. This pre-processing stage can be configured by several parameters. This paper optimizes these parameter settings by using evolution strategies. It turns out that this optimization reduces the required energy and the number of wrongly generated pixels by about 15%, respectively.

Categories and Subject Descriptors
J.7 [**Computer Applications**]: Computer in other Systems–*Industrial control, Process control.*

General Terms
Algorithms, Performance, Design, Economics, Reliability

Keywords
Image processing, evolutionary algorithms, industrial application

1. INTRODUCTION
Print media, such as newspapers, journals, books, and flyers, are still important information sources in everyday life. These media are the result of a well-established printing process in which a printing machine uses a printing plate to distribute liquid color onto the actual media, i.e., paper. In this process, the printing content, i.e., letters, symbols, and graphics, is encoded on the printing plate's surface in form of a physical structure. This structure consists of reverses and dots, with the latter being the means to bring the color onto the paper. This process is widely known as *offset printing*, and sketched in Figure 1.

Every page requires a page-specific printing plate, which is generally prepared in three steps. First, a steel or aluminum plate, covered with some light-sensitive polymeric material, is brought into another machine, called a *setter*, which is depicted in Figure 2. Then, the setter's exposing unit transfers the page's content onto the printing plate's surface. This content is normally stored as a digital image, which is a collection of individual pixels, on a (host) computer.

During the exposure, the polymeric material changes its physical properties: those areas that are exposed to light hardens, the others not. Finally, a subsequent chemical process removes the not-hardened material such that later on, the exposed areas are able to transfer the liquid color. It might be mentioned here that some setters utilize laser light, others ultraviolet light with a wave length of about 360nm to 450nm.

Due to the printing plate's size and the required resolution, the image cannot be transferred in a monolithic form. Rather, as is illustrated in Figure 3, the image is divided into stripes. In state-of-the-art setters, an entire stripe is processed by moving the exposure head from left to right or vice versa. During these movements, the image data is loaded and appropriately shifted line by line through the head's optical system (see, also, Appendix A).

For "regular" print media, such as paper, the offset printing process is well established. Since offset printing is of high quality and cost effective, current efforts try to also utilize it for other material, such as cardboard, wall papers, and the like. These new materials, however, are characterized by a much higher roughness, which in turn requires substantial modifications of the printing plate, called *flexo printing plate*: In order to ensure high-quality prints, the difference between the printing plate's dots and reverses has to be much more pronounced. This in turn imposes new problems to the exposing process: the main problems are, as Section 2 discusses, that the printing plate's dots lack physical stability and that the image runs out of focus due to the polymeric material's thickness. The exposing process is defined by several parameters, including the light's intensity, the exposure time, and the point of focus.

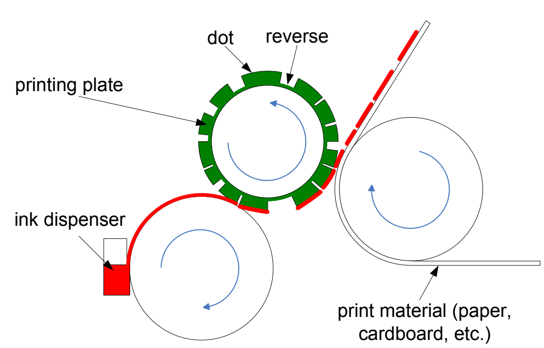

Figure 1: Simplified print process

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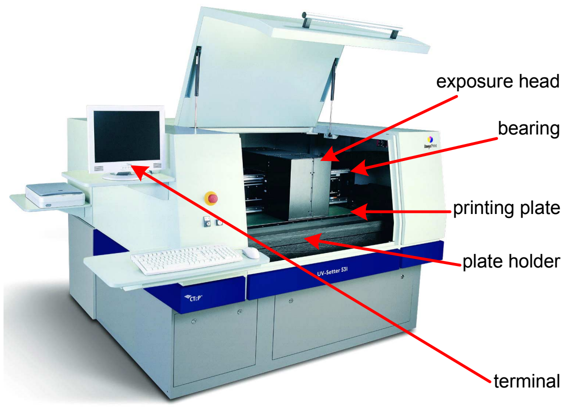

Figure 2: The UV-Setter, courtesy of Punch Graphix Prepress Germany, Ltd.

In order to alleviate the problems mentioned above, Section 3 proposes an image preprocessing method that processes images the same way the visual system of mammals does. This neural-network-based approach is defined by a set of parameters, called connections. With respect to the printing's quality, these parameters are highly dependent on each other, and multi modal by their very nature. Therefore, Section 4 applies evolution strategies to evolve them.

The results, as presented in Section 5, indicate that the proposed approach leads a homogenous distribution of the light's energy, and therefore, a high printing quality. Furthermore, optimally evolved parameter sets may reduce the exposing time by about 15%. Section 6 concludes this paper with a brief discussion.

2. PROBLEM DESCRIPTION

As has been mentioned in the introduction, flexo printing plates are characterized by a significantly increased thickness of the light-sensitive polymeric material. This thickness means that the exposing light has to travel a longer distance *through* this material. Along this distance, the light diverges, since it has previously passed a lens system (see, also, Appendix A).

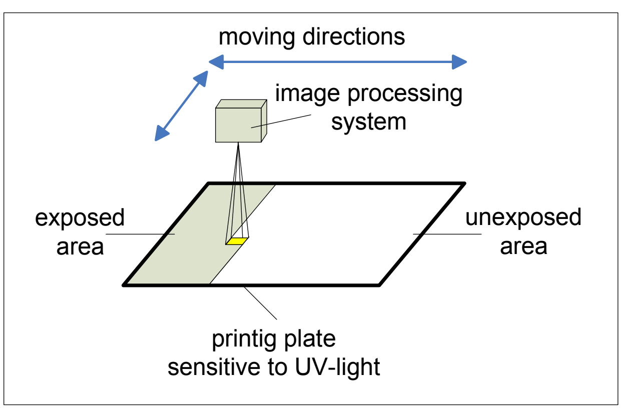

Figure 3: Illustration of an exposing process

The problem is that flexo plates cannot neglect this light divergence; rather, they have to deal with and compensate for it. Because the light diverges along its way through the polymeric material, a blob has varying diameters along the z-axis. This effect is illustrated in Figure 4, which shows four cross-sections along the z-axis. The increased size of the exposed area leads to two different effects.

First: Due to the increased size of a blob in the bottom layers of the plate, the energy per unit area decreases. In order to have enough energy to properly harden the polymeric material, the total amount of light energy has to be increased. Due to mechanical constraints, this can be achieved only by slowing down the exposure process. This compensation, however, contradicts economical demands, which desire the process to be as fast as possible.

Second: an increased amount of global light energy also widens a pixels size at the top layer (light pixels are circles, printing pixels are squares). This degrades the printing quality significantly, because spurious pixels may appear on the printing material, In this paper, the term “spurious pixel” refers to pixels that appear on the print media, even though they are not in the data file.

In summary, in order for single (isolated) pixels to properly appear on the printing plate, the light energy has to be increased, which leads to other problematic effects, e.g., spurious pixels. In contrast to very thin printing plates for regular paper material, flexo plates suffer from these effects and thus have to compensate for them.

3. THE PROPOSED APPROACH

Section 2 has discussed that flexo printing plates have to cope with certain exposure problems. From a technical point of view, the preparation of a printing plate can be seen as an image processing task in which a digital image is brought onto a physical plate.

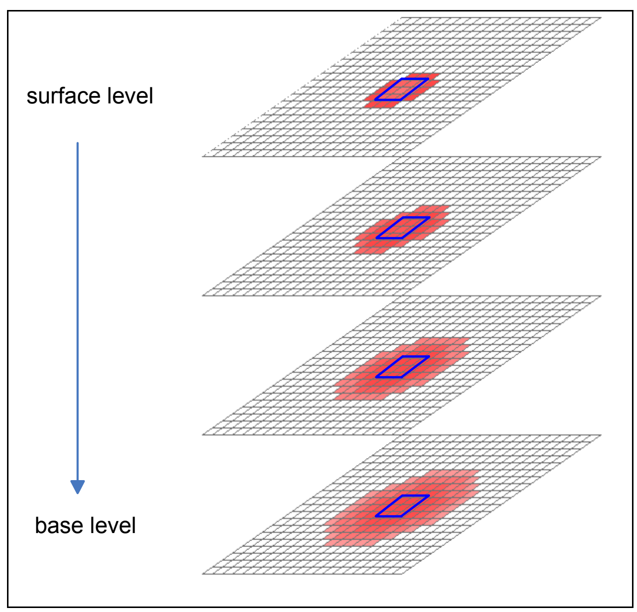

Figure 4: Widening of a single, freestanding pixel (blue border)

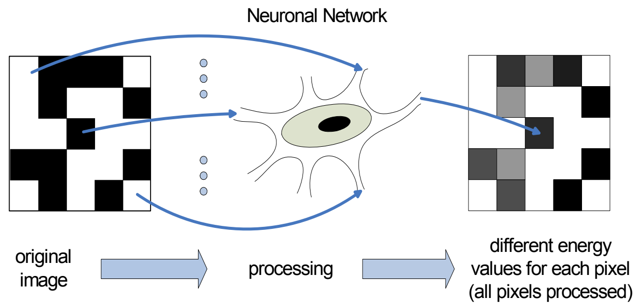

Figure 5: the neural network approach

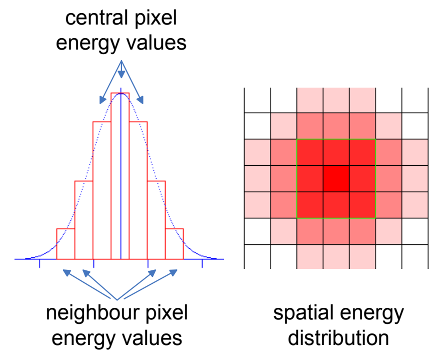

Figure 6: Exposure settings

The approach presented in this paper inserts an image preprocessing stage that is executed during or prior to the exposure of the plate (see, also, Section 6). The design of this preprocessing stage draws some inspiration from how the mammalian visual system processes images: for every "pixel", the brain applies local filters all of them having the same structure and processing the pixel's neighborhood [7]. This visual system operates highly parallel, fault tolerant and reliable, and adaptive by its very nature. Thus, the approached proposed here is called *neurally preprocessed printing plate* or NP³ for short throughout this paper.

Figure 5 illustrates that like the biological visual system, NP³ considers a *virtual* neuron for every pixel. This neuron senses its corresponding image data, called the central pixel, as well as the pixel's neighborhood, which might be of 3x3 or 5x5 in size. This neuron calculates the pixel's exposure I from the image data C_P as follows:

$$I = \sum_P w_p C_p \qquad (1)$$

with w_p denoting a connection weight or strength. Since all pixels are handled in the same way, all neurons and thus all connections w_p are identical.

The proposed approach seems rather simple and straightforward. However, the connections w_p are not independent of each other. Because of the light's divergence, every pixel also influences its neighbors by injecting some light energy to them. This in turn affects the determination of optimal values for the connections w_p. Both the strength and the number of influenced pixels depend on the chosen light geometry as is illustrated in Figure 6.

4. METHODS AND SIMULATION

This section describes the evolutionary approach, defines the fitness function, and sketches the simulation environment used for the experiments.

The evolutionary approach:

Because the parameters w_p are real-valued, exhibit significant epistatic interaction, and are multi-modal with respect to the fitness function[1], this paper uses evolution strategies [4] for the optimization of the connections w_p.

[1] These properties have been observed by preliminary experiments that have involved classical steepest-descent methods.

Evolution strategies in general are a member of the class of heuristic population-based search procedures known as *evolutionary algorithms* that incorporate random variation and selection. Evolutionary algorithms provide a framework that mainly consists of genetic algorithms [1], evolutionary programming [2], [3], and evolution strategies [5]. A genetic algorithm maintains a population of μ individuals, also called parents. In each generation, it generates λ offspring by copying randomly selected parents and applying variation operators, such as mutation and recombination. It then assigns a fitness value (defined by a fitness or objective function) to each offspring. Depending on their fitness, each offspring is given a specific survival probability.

Unless otherwise stated, this paper has used a (1+5)-evolution strategy, since the pertinent literature [4] indicates that this configuration of the number of parents and offspring yields the highest sequential fitness. The chosen notation also indicates that the parent of the next generation is selected from union of the current offspring and the previous parents. In addition, the chosen evolution strategies have also employed a step size adaptation.

Furthermore, this paper considers rather small population sizes, since the practical fitness evaluation is a very time-consuming process. It should be mentioned here that the evolutionary algorithm initializes its population members with $w_{p(i!=4)} = 0$ and $w_{p4} = 8.5$, which represents the conditions without the preprocessing stage.

The fitness function:

The goal of the evolutionary process is to evolve a weight matrix, such that all pixels appear as given in the digital data file: that is, for black pixels the total light energy has to be above a threshold T, such that it withstands the chemical process; and obviously for white pixels, the total light energy has to be below this threshold. Mathematically, the fitness F_p for a single pixel is calculated as follows:

$$F_p = \begin{cases} (T - E_p)^2 \Leftarrow E_p > T; C_p = 1 \\ 5(E_p - T)^3 + 100 \Leftarrow E_p < T; C_p = 1 \\ 5(E_p - T)^3 + 100 \Leftarrow E_p > T; C_p = 0 \\ (E_p)^2 \Leftarrow E_p < T; C_p = 0 \end{cases} \qquad (2)$$

with T denoting the threshold value, E_p denoting the energy value of Pixel p and Cp denoting the current state of pixel p in that way that '1' constitutes a black pixel and '0' constitutes a white pixel, respectively. The offset "100" has been introduced in order to pronounce correctly exposed pixels. For illustration purposes, Figure 7 depicts the two cases, i.e., black and white pixels, of F_p. Then, the fitness function F sums the individual contributions F_p overall pixels P as follows:

$$F = \sum_{p=1}^{P} F_p \ . \qquad (3)$$

Simulation environment:

Because the evaluation of every fitness value by means of preparing a physical printing plate is way too costly and time consuming, this paper has used a physically plausible simulation software.

This simulation software allows for the processing of arbitrarily configured test images, provides the user with an appropriate graphical user interface, and supports the setting off all relevant parameters, such as population sizes, lighting conditions, plate parameters, etc. For the experiments reported in this paper, the simulation software has used the test image shown in Figure 8.

In order to yield a precise evaluation, the simulation subdivides every pixel into 3x3 subpixels. This way, the simulation software accounts for the fact that a "light pixel" is of circular geometry, whereas the image data contains square-shaped pixels. An example is illustrated in Figure 6. The Figure also shows that the simulator treats the light beams as fine-grained normally distributed values. It can be seen that the Gaussian-shaped light beams account for the effect of overlapping pixels in a natural way.

5. RESULTS

In order to asses the quality of the NP³ approach proposed in this paper, this section also considers printing plates that are exposed in the usual way, that is without any further preprocessing.

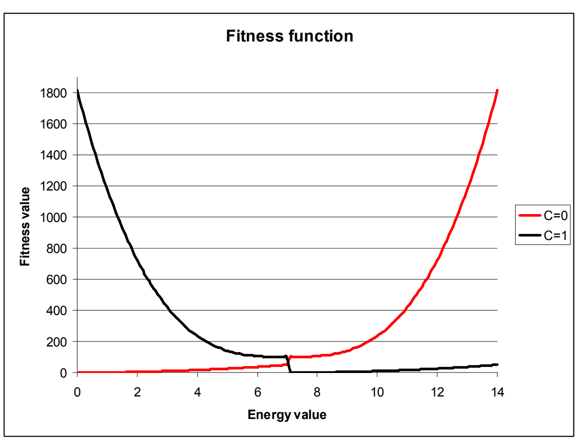

Figure 7: Fitness function

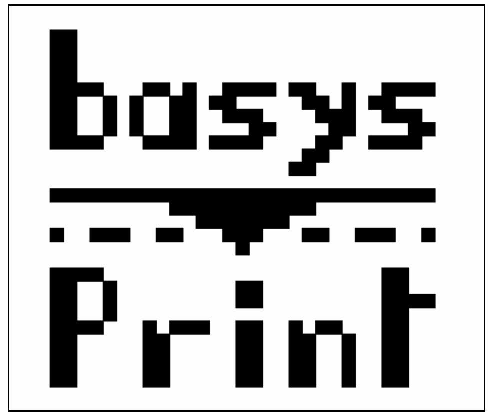

Figure 8: Test image

For the chosen test image, Figure 9 shows how the fitness evolves over time. It can be seen that in comparison to the standard exposure process, the evolution strategies reduce the fitness values (actually, error values) by about 60%.

Figure 11 shows how the improved fitness affects the printing plate. It can be seen that in comparison to the standard exposure procedure, shown in Figure 12, the evolved preprocessing stage has significantly reduced number of spurious pixels.

For presentation purposes, Figure 10 shows two corresponding blow ups. Already in this very small subfigure, the evolutionary algorithm has reduced the number of wrongly exposed pixels (red) from 32 to three. In addition, the preprocessing stage significantly reduces the total amount of the light energy by about 12%. Furthermore, the energy is much more homogeneously distributed, which has additional advantages for the photo/chemical process, which is, however, beyond the scope of this paper.

It might be argued that other configurations than the chosen (1+5)-evolution strategy might yield better or worse performance in terms of the experimentation time. However, this question is not in the focus of this paper; rather, the goal is to achieve superior solutions by applying evolutionary algorithms, because standard approaches yielded solutions with limited utility. Furthermore, it might be mentioned again that with respect to physical validations, the population sizes have to be small.

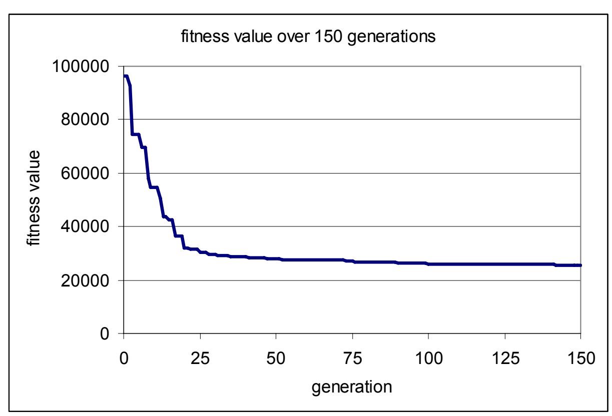

Figure 9: Fitness progress

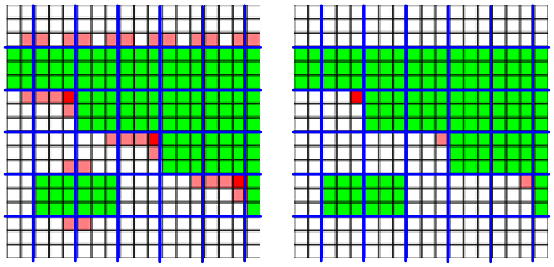

Figure 10: Exposed plates (detail view)

6. DISCUSSION

This paper has presented an application from the area of offset printing. The core of this application is a machine that transfers a digital image onto a printing plate, which is being finished in a subsequent chemical process. Due to economical reasons, current developments try to also utilize offset printing to other media, such as cardboards. These media, however, are characterized by other physical properties, and thus require a modified exposure process.

Since the direct usage of the image data leads to the generation of pixels that are actually not in the image data (spurious pixels), this paper has proposed a preprocessing step, called *neurally preprocessed printing plate,* that yields significant improvements over state-of-the-art, rather standard exposing procedures. These achievements are significant from an economical as well as quality-of-printing point of view. Current developments are integrating these optimizations into available market products.

In the current approach, the optimal values for the (virtual) connection weights w_p depend on the actual image data. This will require an additional, very short adaptation phase for every new image. Even though this adaptation can be executed offline, i.e., on a separate computer, it can be considered a flaw of the current approach. Therefore, further research will be dedicated to the development of an enhanced preprocessing stage in which the optimal parameter settings do not depend on the actual image content.

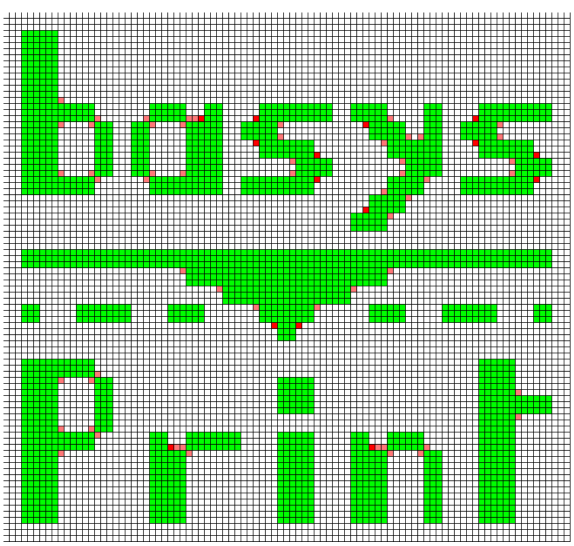

Figure 11: NP³

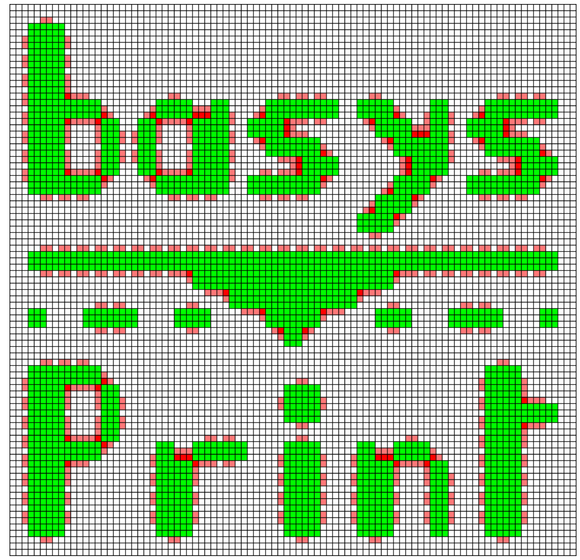

Figure 12: Classical exposed printing plate

Furthermore, future research will be developing a custom-made hardware design, which will be based on state-of-the-art field-programmable gate arrays (FPGAs) [6]. The expected advantage will be that both the adaptation and the actual preprocessing can be done *on the fly* during the preparation of the printing plate.

7. ACKNOWLEDGMENTS

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9. APPENDIX A

Figure 13 shows the lens system of the UV setter used in this paper. A key feature of this particular lens system is the digital mirror device (DMD[2]), which employs 1024*768 individually controllable, tiny mirrors. An attached hardware controller switches every single mirror on and off according to the present image data. The DMD is thus able to individually control the exposure of every single pixel.

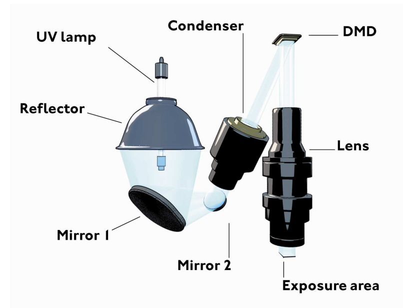

Figure 13: Optical system of the UV-Setter, courtesy of Punch Graphix Prepress Germany, Ltd.

[2] The DMD is manufactured by Texas Instruments Incorporated