Perception Guided Automatic Press Diagnosis

Hila Nachlieli[1], Zachi Karni[1], Shaul Raz[2]
[1]HP Labs Israel, Technion City Haifa, Israel [2]HP Indigo, Rehovot, Israel
[hila.nachlieli | zachi.karni | shaul.raz]@hp.com

Abstract

We present an expert system for identifying print artifacts. The system balances between subjective sensitivities of print quality with an evaluation of the objective machine state (which may result in visible print artifacts). For example, fine bands may appear due to the mis-calibration of one machine component, while low contrast stains may exist on the same printing due to the state of another component. Different markets have different needs and hence may have different sensitivities to the same two artifacts: Marketing collateral customers may be more sensitive to the low contrast stains and less to the fine bands. On the other hand, photo album's customers may be more sensitive to the fine bands, and Direct Mail customers may accept the printing as valid.

To achieve this balance, we combine an interactive expert system with an automatic analysis of dedicated print jobs. The expert system guides the user in classifying the print artifact according to his subjective sensitivities. Utilizing an inline-scanner enables automatic procedures for the detection of artifacts caused by an objective machine state. Benefits of the system include better control of print quality and better use of consumables.

Introduction

Commercial presses are complex physical systems that bring together mechanical, electrical, optical and chemical components and mechanisms to work together in synergy. This synergy and the fine balance between the different components are the source for the normal operation of the press and for the quality of its products. Any deviation from this balance may result in print artifacts and may affect the printed product and its quality.

The complexity of a commercial press and the dependencies between its many components challenges the detection of the source of an artifact. Mathematically speaking, a mapping exists form the different components of the press to the print artifact. This mapping is a many to one function with dependencies between its variables. Many to one mapping functions are usually impossible to reverse and a typical approach to approximate their inverse is to incorporate specific information about the problem. For example, a vertical streak (fine scratch along the print direction) may be the result of a malfunction in several independent components of a press or a combination of a few. Providing only the streak and its location on a customer job may lack important information, such as the colors in which the artifact appears, for isolating the malfunction component. Such problems are commonly solved using the try and error approach.

Accurate operation of all the press's components guarantees good print quality. Still, many of the drifts in press states lead to

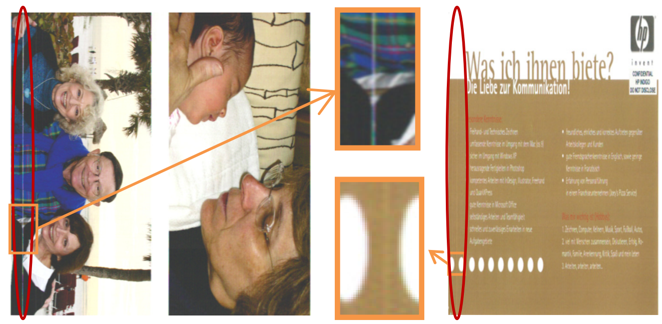

Figure 1: Left: a vertical streak in photo album page is very noticeable and will cause the print to be rejected. Right: the same vertical streak in a brochure page, although visible the job is still considered valid.

hardly noticeable artifacts and printing may continue even with small deviations in one or several of the press's components. Once an artifact is significant, the common practice is to halt the printing process until full resolution of print quality. Typically the detection of an artifact is preformed manually by the press operator. Modern presses utilize an inline-scanner or camera that drives the automation of this procedure [1][4][8][10].

The significance of an artifact is highly subjective and depends on the purpose of the print and on the sensitivities of the customer. For example, Figure 1 shows two different types of printings: the left is a page of a photo book and the right is a page of a brochure. In both the same vertical streak exists on the left of the page (highlighted by a red ellipse). It is clear that for a photo book such an artifact is unacceptable and the press must be stopped until recovery. Nevertheless, for the brochure, although the artifact is visible, the job may still be valid as long as it is accepted by the customer. Figure 2 illustrates a print with two types of artifacts. Some customers may be sensitive to the band artifact across the page, taking the stains on the top right corner to blend with the gray rocks. Others may be sensitive to the stains, regarding the band as an insignificant low contrast artifact. If the image is targeted to a high quality catalog, both artifacts are inacceptable. However, if the target is a standard quality brochure, both artifacts may be accepted. Therefore, the challenge is to identify the problem that most bothers the customer. Having identified the specific problem, we use our understanding and knowledge about the physics of the press, to pinpoint on the malfunction component and to recommend the proper resolution.

In this paper, we propose a solution that combines an interactive expert system with an automatic analysis of dedicated print

Figure 2: An image with two Artifacts: a band and stains. A customer may be sensitive to the white stains on the top right corner while another may be sensitive to the band artifact across the page.

jobs. The system interacts with the press operator in a very simple manner to obtain coarse classification of the artifact that bothers the customer the most. Depending on the complexity of the artifact, we add an automatic procedure that refines the classification based on the objective perceptual severity of the artifact. The objective severity for each type of artifact is learned in advance from the opinions of a representative group of experts [5][6][7]. Using both descriptions, the manual classification and the automatic refinement, we identify the component that causes the artifact.

Prior Art

Diagnosis and automatic calibration

Several diagnosis and automatic calibration systems exist today such as the inline spectrometer by Xerox that enables color monitoring [11]. ImageXpert [12], AVT [13] and IVT [14] offer offline print analysis procedures and platforms. Kodak NexPress Intelligent Calibration System (ICS) offers off-line color uniformity calibration. Kodak's NexPress SX Operator Support System [15] and Heidelberg offer a suite of diagnosis tools in which the operator chooses the tool for his specific scenario. We propose a holistic solution that guides the operator throughout the troubleshooting process, from printing to resolution.

Print quality evaluation

A principle aspect of our solution is an automatic identification of specific print artifacts on specially designed print jobs and the evaluation of the artifacts' severity. Automatic analysis of dedicated print jobs is already in use especially for automatic calibration procedures that measure the physical features of the artifacts [2]. Identification of significant artifacts on printings was also studied, for example [3][9]. Measured artifact severity represents the objective artifact severity, if the agreement between the measure and the average severity evaluations given to the artifacts by a representative group of evaluators, is higher than the mean agreement in the group [6][7].

Our Method

Our method integrates an interactive expert system with an automatic analysis of a dedicated print job. Our system is initiated manually by the press's operator upon artifact detection. Using few simple questions, the system classifies the artifact into coarse categories such as: vertical streaks, horizontal bands and stains (a streak is demonstrated in Figure 1 and a band and stains are illustrated in Figure 2). This classification identifies the subjective sensitivity that mostly catches the operator's eyes.

There are cases in which coarse classification is sufficient for a complete resolution. However, such cases are very rare and therefore finer classification into sub-categories is required. Figure 3 demonstrates such a difficulty that prevents the operator pinpointing on the right artifact category. The figure shows a vertical strip cropped out of a page printed in solid Cyan. The red arrows aim at areas that are slightly brighter – those are horizontal bands A short analysis of the bands artifact leads to the conclusion of a low frequency bands with a known spacing between them for which a known solution exist. Nevertheless, not all bands look alike and not all are equally noticeable with respect to their level of brightness and width. The operator may easily fail to notice the top band, resulting in a single band analysis that would lead to a completely different resolution, hence a replacement of an incorrect component.

We identify the finer classification as the objective machine state and suggest a full automatic procedure for its implementation. For simplicity, we will concentrate on two major artifacts: streaks and bands. When the manual stage completes with a classification into these categories, it initiates the automatic printing of a special designed job. Figure 4 shows the special jobs for the horizontal-bands case (left) and vertical-streaks (right). The jobs were specially designed to capture artifacts of the selected category and to enable fast and accurate analysis. The special job includes the common separations installed in a press (Cyan, Magenta, Yellow and blacK). For example, the print jobs in Figure 4 include four separations: black, cyan, magenta and yellow. In addition, the special job for streaks adds additional separation that combines all the four separations (named "multi"). Each page is printed in at least two brightness levels since some artifacts are more visible on bright background and some on dark. After the special job is printed, the pages are automatically scanned using an inline-scanner, and analyzed. The analysis is done by Artifact Specific Severity Evaluation Tools (ASSET). Each ASSET was developed to detect a specific case of the artifact and to evaluate its severity. Each ASSET is used only when the related category is identified, on the relevant print job. The current system includes ASSETs for bands and streaks. These ASSETs are basically press independent. However,

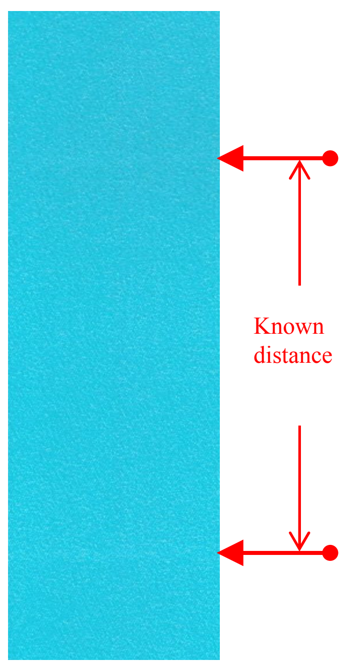

Figure 3: A burn strip problem in Cyan , and the location of the automatically detected horizontal bands with known distance between them [please enlarge the digital version of the image to better see the bands].

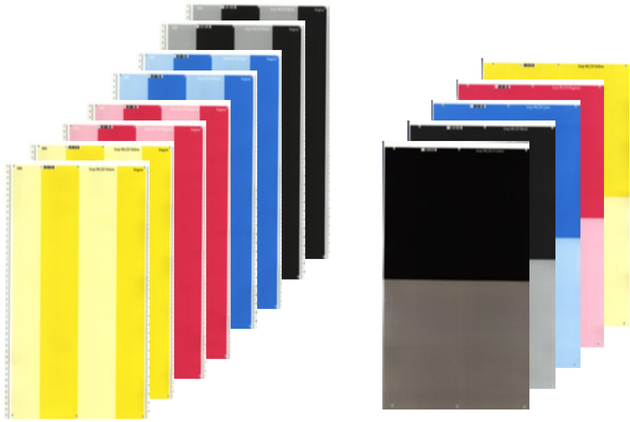

Figure 4: Diagnostic jobs for a four-separation configuration. Left: a job for detecting horizontal-bands. Right: a job for detecting vertical-streaks.

specific tuning to the individual industry preferences may be required. The result of the automatic detection stage is a list of locations of bands or streaks with their severity.

The final stage is the analysis of the detection results. This analysis is implemented as a decision-tree such as the one illustrated in Figure 5 for streaks detection and for the case of the "multi" page. In this example, a detection of streaks in the "multi" page leads to the analysis of the differences between their severities levels against the dark and light background. The result leads to a conclusion followed by an action which is then propagated back to the operator's console.

Results

To verify the performance of our system, we divided it into two parts. The first is responsible for the detection of an artifact using the different ASSETs and the second to the analysis of the results using the decision tree and for the final conclusion and action.

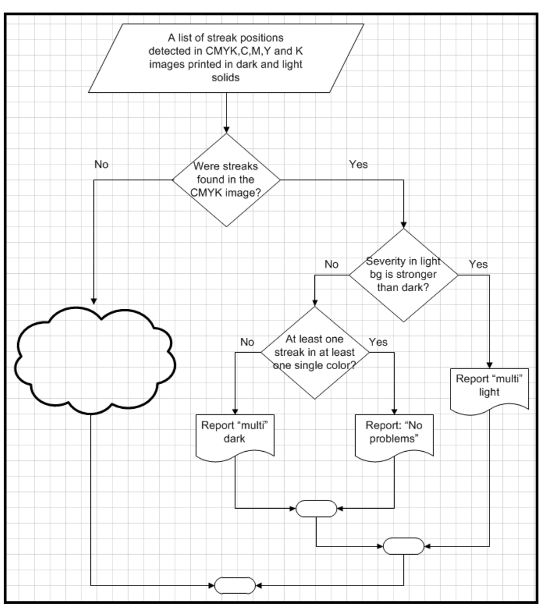

Figure 5: A partial decision-tree used in the analysis stage.

The ASSETs Qualification Test was used to verify the degree of correlation between the automatic rankings of an ASSET and the human perception. Each of the ASSETs was qualified against a committee of people who were requested to rank the severity of artifacts on printed sheets. The results of the tests have twofold: fine-tuning of the relevant ASSET and verifying high correlation between the automatic and human approaches. The qualification approach is described in [7]. Qualification results for a specific ASSET are described in[5].

To test the conclusions and actions reported by the analysis stage using the decision tree, we simulated specific artifacts and traced their path along the decision tree. Two types of simulations were used: "faked" scanned sheet that mimicked a specific artifact and intentionally using malfunctioning components within the press.

Conclusions

We presented a full diagnosis solution for commercial printers and presses. The solution is general and not limited to a specific type of artifact. Our solution relays on both: subjective input from the operator and automatic objective analysis. The solution starts with a coarse subjective classification of the artifacts. For simple artifacts classes this stage is sufficient. For complex artifact classes additional information is required. The solution imitates an automatic procedure that prints a specially designed job, scans it using an inline-scanner and analyzes the scan using a specially designed algorithm. The results of the analysis and the action to be taken are reported back to the operator. Field tests of our system are in beta stage and will be delivered to the customers as an overall solution in future releases.

References

[1] O. Barkol, H. Kogan, D. Shaked, M. Fisher, "A robust similarity measure for automatic inspection", ICIP 2010, pg 2489-2492. (2010).

[2] W. Jang, M.C. Chen, J.P. Allebach, G.T.C. Chiu, "Print Quality Test Page", Journal of Imaging Science and Technology, Vol. 48, pp. 432-446. (2004)

[3] B.S. Lee, "Characterization of Opponent Channels, Automated Detection of PQ Defects and Green-Noise Mask Design by Dual-Metric", PhD Thesis. (2006).

[4] E. Malamas, E.G.M. Petrakis, M. Zervakis, L. Petit, J. Legat, "A survey on industrial vision systems, applications and tools", Image and Vision Computing, Vol. 21, pg. 171-188. (2003).

[5] H. Nachlieli, D. Shaked, S. Druckman, M. Shalev, Y. Yona, "Automatic Mechanical-Band Perceptual Evaluation", NIP25: 25th International Conference on Digital Printing Technologies, pg 20-24. (2009)

[6] H. Nachlieli, D. Shaked, "Qualification of Quality Measures", ICIS2010, (2010).

[7] H. Nachlieli, D. Shaked, "Measuring the Quality of Quality Measures", IEEE Transactions on Image Processing, vol 20(1), pg 76-87. (2011).

[8] T.S. Newman, A.K. Jain, "A Survey of Automated Visual Inspection", Computer Vision and Image Understanding, Vol. 16, No.2, pg. 231-262. (1995).

[9] H.S. Rosario, E. Saber, W. Wu, K. Chandu, "Streak detection in mottled and noisy images", Electronic Imaging Vol. 16. (2007).

[10] H. Shang, Y. Chen, W. Yu, Z. Zhou, "Online auto-detection method and system of presswork quality", International Journal of Advanced Manufacturing Technology, Vol. 33, pg. 756-765. (2007).

[11] http://www.xerox.com/digital-printing/digital-printing-press/color-printing/xerox-igen4/enus.html
[12] http://www.imagexpert.com
[13] http://www.avt-inc.com
[14] http://ivt.sourceforge.net/index.html
[15] http://graphics.kodak.com/KodakGCG/uploadedFiles/Products/Printers_and_Presses/Production_Color/nexpress%20business%20model.pdf

Author Biography

Hila Nachlieli works for Hewlett-Packard Laboratories Israel on inline print-quality evaluation. Her research interests include voting theory, machine learning and image processing. She received her PhD in Physics from the Technion - Israel Institute of Technology, in 2001 in granular flow.

Zachi Karni received the BSc degree in Mechanical Engineering and the BA degree in Computer Science both from the Technion in 1996/7 respectively. He received the PhD degree in Computer Science from the Technion in 2004. He was a post-doc at the Max-Planck Institute for Information between 2004-6. He is currently a Senior Research Scientist at HP Laboratories, Israel. His research interests include computer graphics, geometry processing, modeling and image processing. Dr. Karni is a member of ACM SIGGRAPH and chairing the SIGGRAPH Local Chapter in Israel.

Shaul Raz is currently a system engineer at BiosenseWebster. Shaul made his three degrees in physics at the Technion Haifa. Both his MA and Ph.D. thesis were on fuel cell research. He joined HP-Indigo where he worked for 10 years in two roles: first as physicist he worked on many multidisciplinary liquid electrophotography printing (LEP) technology issues. Later as system engineer developing expert systems for to identifying and troubleshoot print quality defects for LEP systems.