AI Supported Printing on Various Media for Industry Printing

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Despite the ongoing trend toward a paperless office, OKI has set the expansion of industry printing business, which it expects will still grow, as a priority measure in its Mid-term Business Plan 2019. Unlike general office printing, industry printing involves printing on media (hereinafter referred to as print media) of various materials and thicknesses. The print media handling capability is one of the significant factors in printer differentiation.

This article introduces OKI's effort to automate the improvement of printing failures using artificial intelligence (AI), which is a measure being implemented to strengthen the printer's print media handling capability.

Characteristic of Industry Printing

Industry printing refers to the creation of printed matter specialized for a specific business in a specific industry such as medical, retail and manufacturing. Unlike printing in offices, printed matter in industry printing has an important role and value in the value chain of the business. Especially, when the printed matter itself is sold as a product or used as part of a product, the quality of the printed matter has a large influence on the product value. For example, OKI's A3 MICROLINE*1) VINCI*2) printer is often used to print invitation cards for a wedding and print photos of the bride and groom on labels for wine bottles or packages of sweets given away as thankyou gifts. In case of wedding invitations, heavy weight paper with a glossy coating or color paper with a glittering finish is used. Transparent film with adhesive is used for wine bottles and heavy weight paper for sweets packages. The characteristic of these printings lies with the use of various print media (hereinafter referred to as special media) depending on the purpose.

Special Media Handling and Problems

There are various kinds of special media including plain paper, heavy weight paper, banner paper, washi (traditional Japanese paper), cardboard, film, synthetic paper, label and laminated paper just to mention a few. Customers utilizing printers are providing printed matter with higher value using the special media in an effort to expand their business. Therefore, adjusting the printer settings according to the special media used and obtaining the proper image quality is extremely vital.

MICROLINE VINCI has been designed with special media capability to a certain extent, and it can produce stable prints on a wide range of printing media as compared with general office printers.

However, there are often cases when the standard adjustment menu of the printer cannot handle the special media that the customer wishes to use. In such cases, OKI engineers are provided with the print media from the customer, and they proceed to find the optimum printer settings as requested by the customer. Hundreds of such requests are accepted annually, including not only in Japan but also from overseas customers in the Americas and Europe. In the process, the following problems were faced by both the customers and OKI engineers.

1) Customers need to wait a long time before receiving a response to a request.
2) Customers need to respond to Q&A with OKI engineers.
3) It is difficult for customers to try out multiple types of special media.

In order to solve the above problems, OKI is developing technology to automate the adjustment of printer settings for special media, which has been carried out by the engineers, using AI and to provide the settings to customers as a cloud service.

Handling Special Media using AI

As a method to automate the adjustment work done by engineers, a model that predicts the optimum printer settings for special media using AI technology based on machine learning (hereinafter referred to as prediction model) is being developed.

As shown in **Figure 1**, the prediction model derives optimum printer settings through machine learning based on learning data consisting of input and training data.

*1) MICROLINE is a trademark of Oki Data Corporation. *2) VINCI is a registered trademark of Oki Data Corporation.

The input data contains the following three pieces of information.

1) Information on the special media for which the printer is to be adjusted
2) Feature value obtained from printing failure image
3) Printer settings when printing failed in 2)

The training data is printer settings that either solve or provide the best improvement to the printing failure occurring with a certain special media.

Learning data is a pair set of input data and training data corresponding thereto, and it is created from numerous data covering various printing failure conditions so that optimum printer settings can be predicted for a printing failure occurring with an unknown special media.

Specific efforts related to the creation of the prediction model are introduced below.

Input Data

For machine learning to work effectively, it is necessary to find the determinant used for predicting the printer settings appropriately and provide that determinant as input data. Therefore, using correlation analysis, information having high correlation with the printer settings is searched and three pieces of information (1) media information, (2) feature value of printing failure image, and (3) printer settings at the time of printing failure were adopted as input data. The following describes how these three input data were selected.

(1) Media information

The special media can be classified into the types shown in **Figure 2**. The information for each media includes thickness, material, density, coated or uncoated, etc. In determining which information is to be adopted as input data, a large number of special media from each type was obtained and actual printing/analysis was performed. Then, media information that was highly correlated with the printer settings was adopted.

However, since there are many different kinds of special media, it is difficult to cover every existing media. Therefore, it was decided to limit the types of media. For that purpose, an examination was first done to determine the actual types of special media that were requested to the OKI engineers for adjustment. Then various media were selected from those with high demand.

The result of the examination into media receiving adjustment requests is shown in **Figure 2**.

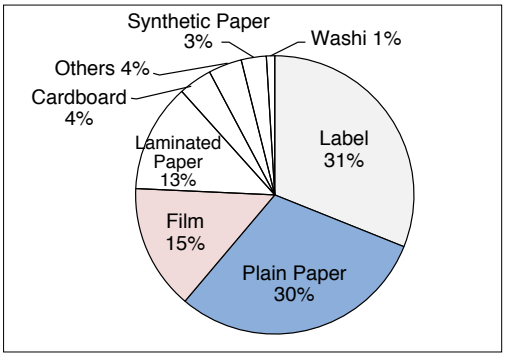


Figure 2. Percentage of Print Media Requested for Adjustment

Following the result of **Figure 2**, a large number of special media classified as label or plain paper were obtained for printing and analysis. The analysis revealed that among the media information, media thickness and material had the largest correlation coefficient with the printer settings. Hence, these two factors were used as input data.

(2) Feature value of printing failure image

In an electrophotographic printer, transfer voltage and fusing temperature are the main printer settings that have

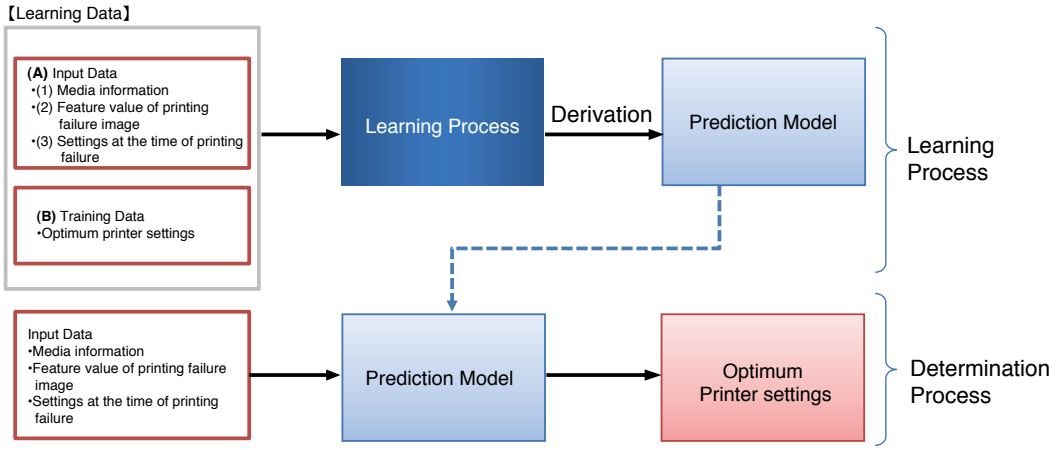


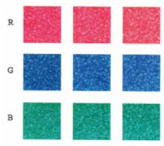
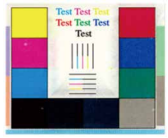
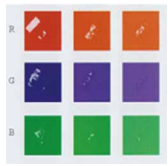
Figure 1. System Process Flow

been used to adjust print quality from the past. When these two settings are not optimized and are either too high or too low for the special media, various printing failures occur.

Consequently, printing failures appear as various symptoms in the images printed on the media. Conventionally, OKI has classified the symptoms of printing failures into a number of groups and assigned a printing failure level to each symptom. Among the failures, it is known that the symptoms shown in **Table 1** have clear relationship with the printer settings (transfer voltage and fusing temperature). Therefore, the symptoms and failure level were extracted from the failure image by applying image processing and were used as input data.

Table 1 also shows the relationship between specific printing failures (symptoms) and printer settings.

Table 1. Symptoms of Printing Failures

Type of Printing Failure	Cause and Symptoms
Faded Color 	Transfer voltage is too low and toner is not sufficiently transferred to the media resulting in faded colors
Spread Specks 	Transfer voltage is too high and toner is not sufficiently transferred to the media resulting in spread specks
Migration 	Amount of transfer charge is insufficient to hold the toner on the media resulting in the toner migrating from the predetermined position
Fusibility Failure 	Fusing heat/pressure is insufficient to adequately fix the toner resulting in the toner to peel when rubbed
Toner Slippage 	Fusing heat/pressure is insufficient and toner melts at a position deviating from the predetermined position resulting in sections with low toner density
Mottle 	Fusing temperature is too high and too much toner is dissolved resulting in formation of spot-like patterns

The process of extracting and assigning levels to the symptoms as shown in **Table 1** is called feature extraction process. Unlike identifying people or vehicles from images, symptoms of printing failures appear in the whole image, thus several feature extraction methods suitable for capturing the feature of the symptoms were selected. The methods were compared and verified, and the most appropriate feature extraction method was chosen.

(3) Printer Settings at the Time of Printing Failure

As described above, since there is a correlation between the symptoms of printing failures and the excessive/insufficient transfer voltage and fusing temperature, not only the symptoms (feature value) of the printing failure images but also the printer settings at the time of printing failure were considered as input data.

Learning Data

In creating learning data for use in machine learning, first, several transfer voltage and fusing temperature combinations were tried on each of the media selected in the section, (1) Media information, to produce printed matters with various printing failure levels. From the respective prints, input data 1) to 3) and training data 4) listed below were acquired, and they were configured as a group to create the learning data.

1) Information of media used in the printing above.
2) Feature value data extracted with the feature extraction process from the image created by scanning the printed matter above.
3) Printer settings at the time of printing above.
4) Training data is the transfer voltage and fusing temperature at the time of printing where the print quality was the best among the media printed above.

Although it is desirable that the learning data cover various printing failure conditions, it is difficult to prepare learning data for all symptoms. Therefore, special media adjustments requested thus far were examined and printing failure symptoms with the highest frequency were targeted for learning data creation.

Figure 3 shows the examination result of printing failure symptoms undergoing adjustment requests.

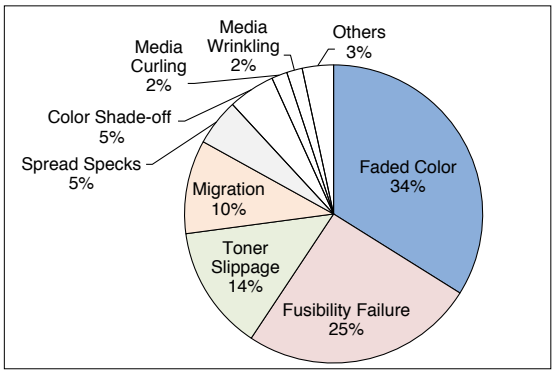


Figure 3. Breakdown of Printing Failures

Based on the result in **Figure 3**, faded color, fusibility failure and toner slippage were selected for learning data.

At present, input data of selected special media and selected printing failure symptoms as well as training data are being collected and implemented learning in parallel to create a prediction model.

Service Provisioning

Effort is underway to provide a service with a simplified procedure as shown in **Figure 4** that will allow customers to carry out the above-mentioned automatic adjustment of special medium on their own.

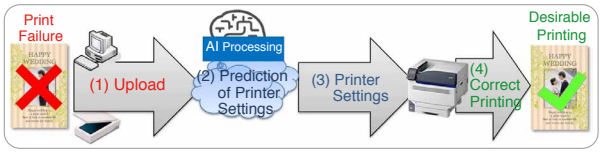


Figure 4. Adjustment Procedure

Procedure

(1) Upload media information, scanned data of printed matter with printing failure and printer settings to the cloud service
(2) Cloud AI predicts the optimum printer settings
(3) Apply the obtained printer settings to the printer
(4) Image printed correctly on media

As can be seen in **Figure 4**, from the customer's point of view, it is possible to eliminate failure and improve print quality in a short time with a very simple operation.

The aforementioned media adjustment requests were those sent to OKI engineers from customers using OKI printers. In addition to those, there are cases when the customer asks a printer dealer for adjustment, or the customer visits a showroom with the special media to request adjustment and confirm the print quality in order to make a purchase decision on an OKI printer. Therefore, this service is not only directed at OKI customers, but also at dealers and OKI's in-house use such as at showrooms.

With this service, for example, a customer operating a print shop that is entrusted with printed matters can print on specified special media with proper quality in a timely manner, thus contributing to the customer's business expansion.

Future Initiatives

Continuous learning data collection is the key to improving the accuracy of printer settings prediction. For this reason, the optimum printer settings that the customers found using the service will be fed back as learning data for the prediction model to improve the accuracy.

Additionally, optimum printer settings found by customers using this service will be archived in a database. This will enable a simpler search for printer settings of special media already registered in the database.

Although the approach introduced here is the application of AI technology to improve printing failures, it is believed that AI technology can be applied to various other fields of OKI's printer business. OKI will continue its effort to further expand customers' businesses, reduce costs and improve productivity. ◆◆

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【Glossary】

Machine learning
One of the research fields of artificial intelligence. In the technology, the human process of learning from experience is performed on a computer by deriving regularities and judgment criteria from data. Then, past events are analyzed and future events are predicted.

Transfer voltage
In an electrophotographic printer, the voltage applied when transferring toner adhering to an electrostatic latent image formed on the photosensitive drum by an LED or laser light source onto paper.

Fusing temperature
The temperature at which the image formed with the toner transferred to the paper is thermally fixed onto the paper.