Current Status of Color Hardcopy Output Technologies

Satoru Honjo
Honjo Research Laboratory
Suginami, Tokyo, Japan

Abstract

Rapidly progressing digital color hardcopy output technologies are challenging to enter into the photo-finishing market. Some special features of the photo-finishing market are mentioned together with the psychological unconscious attitude of print viewing people.

Trends of color hardcopy output technologies in Japan are then described with a stress on photo-finishing applications.

For further improvements of image quality, some advances in dot gain analysis in area modulation type print are discussed.

Introduction
Features of Photo-finishing Market

Digital color hardcopy output technologies are trying to enter into the photo-finishing market. The market has long been supporting the joy of picture taking and viewing.

Such a joy is essentially based on the reconfirmation of one's visual experiences by producing their favorable records in the form of hardcopy. People's desire of fixing their fading visual memories is universal, and the photo-finishing market is deeply related with involuntary behavior or sympathy of human being.

To understand the special nature of the market will help a certain technology succeed there.

Some significant features of the photo-finishing market, the last fortress of silver halide photography, will be examined. In the present paper, the term 'photo-finishing' will be confined to the case of reflection print preparation, since the slide preparing sector does not seem to be much influenced by digital technologies.

Further, in the following discussion, people's involuntary attitude of regarding the information transmitted by light as uniquely genuine is taken into account. According to Plinius, picture drawing originated from a girl in Corinth tracing the profile of her lover cast on the wall prior to their departure, which indicates such human psychological attitude.

Some Empirical Facts

Some empirical facts which seem significant to understand the essential features of the photo-finishing market are cited below.

1. When silver halide photography appeared in the history of mankind, people instantaneously recognized by intuition monochromatic photographic images as the genuine record of the light reflected from the scene.
2. High quality digital prints which are equivalent to photographic one in resolution and S/N are hardly accepted as substitutes for the photographic print if the surface structure is different from that of the photographic print, even though the degree of difference is dimensionally small. Such prints lack in the aura of the photographic print.

In particular, changes in the surface property depending on the image content, such as the gloss fluctuation in xerographic prints depending on image density, tend to give a unfavorable look for photo-finishing application. The significance of print material is shown in the story of preparing portraits of Emperor Meiji.[1,2]

3. A photographic print recording the visual experience of the picture-taker has a subjective significance compared to prints which record objective information taken by a third party.

Such subjectively valuable records must be printed in photographic material as was shown by the experiment carried out and made open by the late W. Rose; Xerox in 70's planned to launch into the photo-finishing market with halftone, black-and-white xerography. W. Rhode (then RIT) was asked to prepare simulation prints with varying screen rulings, which were subjectively evaluated.

Most of the subjects judged that prints with 200 lines/inch or more were satisfactory, and the company decided to adopt this value for commercial development. The late H. Neugebauer, who was then with Xerox, proposed to repeat the experiment with pictures taken by the subjects. The first experiment used pictures taken by professionals.

The result of the second experiment drastically altered; all the subjects answered they would not buy the halftone prints of any screen ruling tested. Xerox gave up the project.[3]

Elucidation

1. Recalling that the photographic technology was quite primitive at its start, one can logically conclude that the

uniqueness of photographic print strongly relies on the favorable brightness compression at highlight. As is well known in the photographic industry, it is almost impossible to remove the low contrast tow from the photographic characteristic curve.

Color photographic prints are often inferior to digital hardcopies in color saturation or fidelity, which indicates photographic prints are favored not by image quality but rather by their power making the viewer intuitively believe that they are genuine and direct products made by the action of light.

2. The significance of surface structure strongly suggests that the power of the photographic print is at least partly due to the resemblance of its appearance to the reflection image on a mirror or a calm water surface. As the reflection image has always a source existence somewhere, the photographic print is recognized as a genuine record of an actual scene. By considering the strength of such an intuitive judgement, photographic print materials must have unintentionally simulated water surface. Two facts suggest a closer relationship of photographic print to water surface than to mirrors; first, mirrors must have been less familiar than water surface for the ancients, and secondly, mirrors often reflect things nearby including their viewers whereby the image is too realistic to give an dimensionally compressed impression.
3. For the recording of visual experience, people like to have prints prepared directly by light to guarantee the genuineness of the record. Artifacts or features indicating indirect processing are not welcomed.

Digital Photo-finishing

For many years, the digital technology side has insisted the merits of image synthesis, versatile image processing, failure saving, etc., without taking into account the above-cited, more essential factors inherent to the conventional photo-finishing market.

Since the mainstream of the market is the recording of visual experience, the coming digital photo-finishing service must consider the third factor seriously. Then, it must satisfy the other two conditions, the first, image quality condition and the second, water surface condition.

As for the former, it is pre-requisite that no harmful artifacts, e.g., one caused by excessive sharpening treatment are recognized. The current inkjet technology is now solving the delicate highlight reproduction with minute dots or diluted inks.

The second condition can be met by adopting the photographic print material for digital output as in the case of Pictrography or Frontier system, both developed by Fuji Photo Film. Inkjet technology is also providing print materials with substantially the same appearance (surface structure) and feel as those of the photographic print.

However, the current inkjet output is too slow while the photographic output requires a collective chemical processing by professional labs. It should be noted that a collective treatment tends to weaken the strength of digital technology which can meet versatile needs.

In the case of hardcopy output, the needs are sometimes difficult to express by word. Necessarily, the ultimate form of digital photo-finishing is printing with PC terminal at home (Fig. 1). As a compromising solution on way to that goal, selected menu will be used at terminals or on internet.

The success of such an intermediate solution depends not only on the quality level of digital infrastructure including the accuracy of monitor, etc., but ultimately on if digital prints can deliver the same aura as the conventional photographic print to viewers.

In Japan, Fuji Photo's Frontier system is becoming popular,[4] and now mainly used for the production of new year's greeting card. Three promising applications of digital photographic service are the production of name card, personalized calendar, and greeting card.

All of these applications indicate that photograph is a medium particularly suited for people to reminisce acquaintances.

Current Status of Color Hardcopy Output Technologies

Hardcopy preparation consists of distributing light-absorbing image former image-wisely, which is thenstabilized. As the unit of the image former becomes smaller, hardcopy image quality generally improves because the image becomes finer along density axis as well as two spatial axes.

In the photographic industry, silver halide crystals with a fixed photographic speed have become smaller and smaller. The similar situation holds for inkjet droplet and xerographic toner. In the case of reflection print, the size reduction proceeds until the image quality (resolution and noise) saturates for the naked eye.

Color photographic print consists of 3μm diameter dye droplets while the current xerographic color print consists of 6~7μm diameter toner. Inkjet printers eject fine droplets as small as 3pl in volume giving dot diameter less than 40μm.

The resolving limit of color photographic paper is determined by the light scattering in the relatively thick emulsion layer, and recent advances are mainly on print permanence or environmentally friendly processing, etc.

Inkjet and xerography both can superimpose two image forming units at most, and then, the size reduction of the image forming unit necessarily demands some colorant content increase in the unit to secure a desirable level of maximum density.

In the case of inkjet, high density dots of about 40μm are still visible at highlights, which adversely affects smooth highlight reproduction. This conflict is solved by the use of diluted inks only at low density regions as in the case of Epson printers for the Japanese market by using print media provided with an ample water absorbing capability.

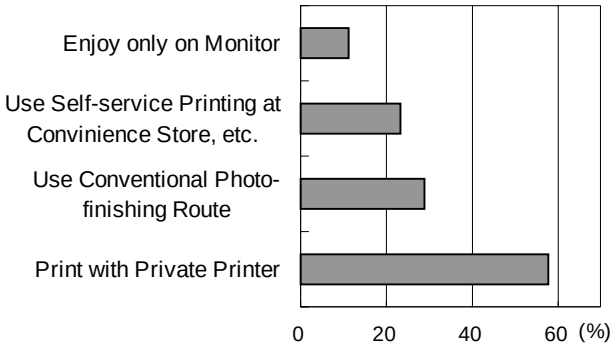

Figure 1. Japanese consumers' answer to the question, "How do you print your shots with DSC?" (Nomura Research Institute, May, 1999)

Inkjet printing media, which must satisfy various requirements often conflicting each other, are now being intensively studied. For photo-finishing applications, some photographic manufacturers are launching with their proprietary resin coated paper substrates.

Xerography surpasses inkjet in output speed, but is more difficult to realize the water surface condition than inkjet, as the toner stays raised from the paper surface after fixing. Further, use of thick substrates demands a simple, linear path, which condition tends to make the printer bulky or else needs an intermediate transfer belt. In the latter case, however, image quality degradation during the dual transfer must be carefully avoided.

Though glossy images are preferred for wider color gamuts, they will result in a gloss distribution depending on image density giving an unpleasant appearance particularly for photo-finishing applications.

Toner size reduction is an orthodox solution, but smaller toner must contain pigments at higher content for the same reason as for inkjet ink. Such small, high density toner is difficult to handle as it is liable to yield high background.

DocuPrint 1250 of Fuji Xerox has evolutionally improved image quality with a new set of toner and optimized process conditions. The technical details are not disclosed, but the image pile height reduced.

The water surface condition can be achieved by uniformly applying a transparent toner layer on a full-color image as Ide et al. tested[5]. His result showed that a fairly large amount of transparent toner is required for a substantially uniform gloss, and that the presence of transparent toner layer acted to reduce image noise by suppressing the lateral flow of color toners.

Small color printers are pursuing easy maintenance or environmentally friendliness with a less stress on image quality.

Advances in Dot Gain Analysis

Xerography and inkjet printing rely on area modulation for tone reproduction. For area modulation systems, dot gain has always been one of the central issues on image quality.

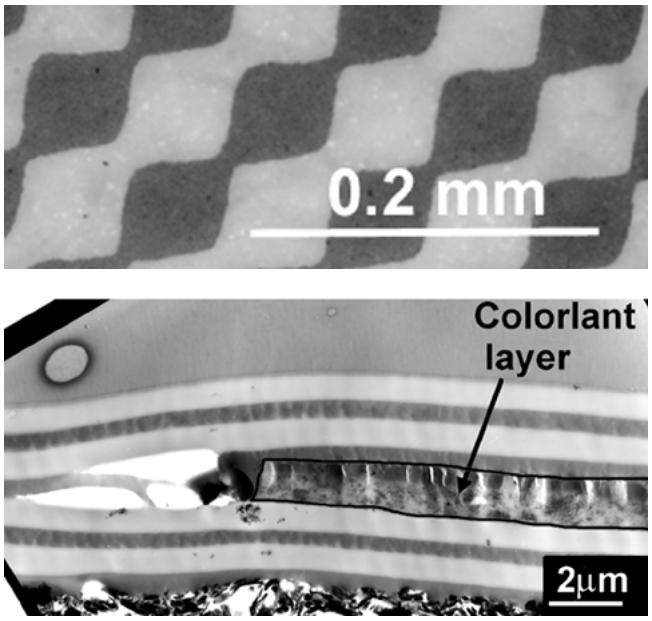

Figure 2. Micrographs (plane and cross-section) of an off-line proof.

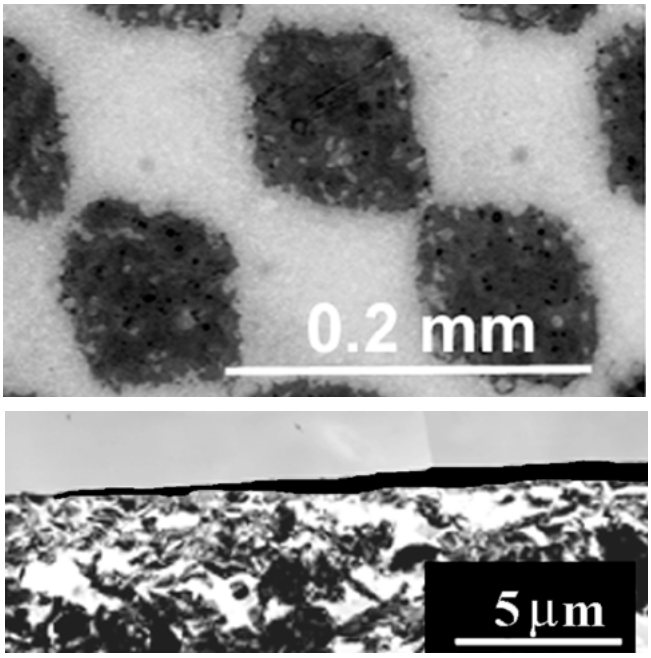

Figure 3. Micrographs (plane and cross-section) of a lithographic print.

Conventionally, the reference of dot gain has been the dot coverage of the original lith film. In most digital workflow where no hardcopy original exists, a new reference is needed.

Ide et al., has recently proposed to use the thickness of colorants at their full coverage area as the reference, and redefined dot gain as caused by the lateral spread of colorant accompanying thickness reduction.[6]

The new definition requires observation of the cross-section of reflection prints. In Fig. 2 and 3, those of an off-line proof and a lithographic print are shown. Such observations generally require time-consuming and careful sample preparation. When the thickness of a colorant layer reduces, the spectral reflectance of the layer changes so as to cause hue shifts. Accordingly, one can obtain information about thickness by means of color measurement.

Figure 4 illustrates such a result as for xerographic step wedges in terms of color shift with area coverage. Qualitatively, the deviation from the line based on simple color additivity rule indicates the degree of dot gain.

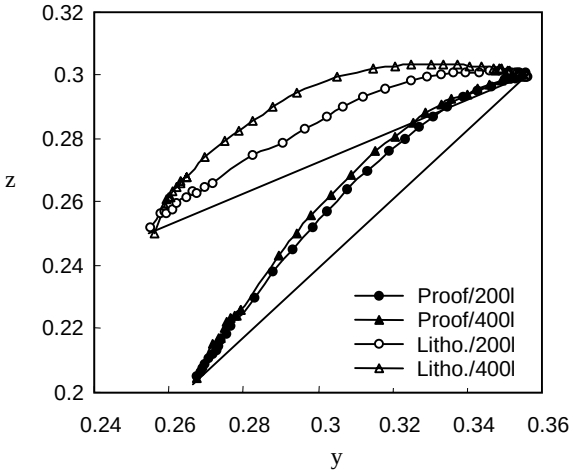

Figure 4. Color coordinates of magenta step wedges of the off-line proofs and the lithographic prints.

Dot gain is caused optically or mechanically. Photomechanical proofs have only optical dot gain while printing and xerography, both including processes where colorants can spread laterally, are attended mainly with mechanical one.

As such a lateral spread takes place usually in an uncontrolled manner, mechanical dot gain acts to increase image noise. The effect of noise suppression exerted by the transparent toner cited in the previous section is to be recalled.

For further improvements in the image quality of digital color prints, image evaluation techniques including the present dot gain analysis will be helpful.

Acknowledgement

The author wishes to thank Mr. Ide of Corporate Research Lab., Fuji Xerox Co. for the provision of experimental data and manuscript preparation.

References

1. K. Taki: ”Portrait of Emperor” (Iwanami Shoten, Publishers, 1988).
2. S. Honjo: *SID 96 Digest*, 943 (May 12-17, 1996, San Diego, CA.).
3. W. Rhodes: In the lecture at *Neugebauer Memorial Seminar on Color Reproduction* (SPIE, Dec., 1989, Ichigaya, Tokyo).
4. H. Nakamura: Prcdgs. *SPSTJ’s Color Lab Seminar* 1999, 16 (June 17, Gotanda, Tokyo).
5. Ide et al.: *Prcdgs. IS&T’s 1998 PICS Conf.*, 114 (May, Portland, Oregon).
6. Ide and M. Kurimoto: to be published in *J. ISJ*., **38**(3), (1999).

Biography

Satoru Honjo received his B.S. degree in Chemistry from Tokyo University and joined Fuji Photo Film Co., Ltd., in 1957. His work in Fuji focused on electro-photographic product development, electrophotographic tone reproduction study, and image design and analysis for various Fuji products including color and, motion picture films, etc. He received doctorate degree in imaging technology from Chiba University in 1991. After his retirement from Fuji, he founded the Honjo Research Laboratory. As an active member of ISJ, he has been in charge of ISJ’s test chart development.