COMPUTER-ASSISTED COLOR SEPARATION INSTRUCTIONAL SEQUENCE FOR PRINTING INSTRUCTORS

Marlow J. Marchant, Ph.D.*

Abstract: The development and evaluation of the Marchant Color Separation System was the focus of this study. The system is a computer-assisted method of producing quality color separations using a microcomputer. It was expressly developed for use in educational institutions, which normally have limited resources for equipment and supplies. The goal of the system is to produce a set of color separation negatives that meet industry standards, has reasonable time requirements, and is affordable for the printing education community.

The system was tested in an in-service seminar for printing teachers and in a process camera photography course for university students. Hypotheses were established to test whether the teachers could produce an acceptable set of separation masks and negatives and if previous experience in teaching, industry, or the use of microcomputers would increase the achievement level. It was concluded that the system enabled teachers and university students to produce a color separation that met industry standards. The data did not support the hypothesis that previous experience would enable teachers to produce masks and separation negatives that more closely matched the listed aim points.

Introduction to the Study

Since Joseph Niepce's first photograph in 1826, photography has captured images for enjoyment and communication (Upton & Upton, 1975). Early photographs were neither clear nor sharp. But later, with the use of silver compounds in the image emulsion, photographs became the best medium for capturing images with detail and clarity.

Though Gutenberg had invented the printing press in the 1440's, illustrations that were printed with type could not include tonal variations. The printing press could not print a photograph, with its broad range of tones, until the invention of the halftone.

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*Assistant Professor of Industrial Education
Brigham Young University

In 1893, Max Levy of Philadelphia manufactured the first commercial glass halftone screens. This process allowed the mass reproduction of the photograph via printing processes (Chambers, 1979). However, the early halftone process was limited to monochrome printing; it could not reproduce the world as humans see it, in color.

From the beginning of photography, inventors worked to develop the color photograph. The first commercially available color plate was the Autochrome, developed by the Lumiere brothers, Auguste and Louis, in 1907. However, it was not until 1935, when Kodak introduced its Kodachrome film, that color photography became widely available (The coming, 1982).

At the same time color photography was being developed, researchers were working on the problem of printing in full color with inks on the printing press. In 1869, Louis Ducos du Hauron described full-color printing and the importance of color balance (Soderstrom, 1980). The ability to capture an image with color photography and then to reproduce that image on the printing press is the basis of modern four-color printing. The importance of the four-color process cannot be underestimated. Consumers no loger simply appreciate four-color priting, they demand it. Figure 1 provides a graphic illustration of the growth of color printing within commercial printing, and forecasts its probable future expansion.

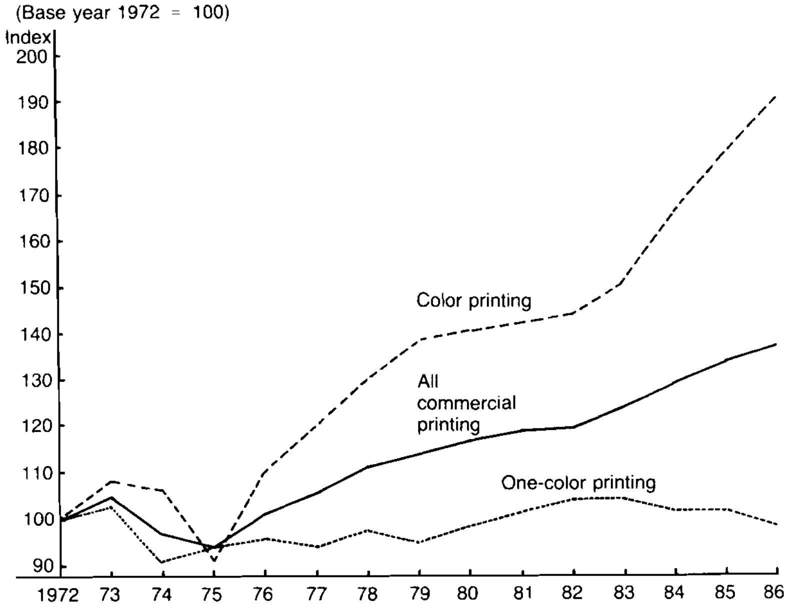

Figure 1. Importance of Color Printing within Commercial Printing (Graphic Arts Technical Foundation, 1982, p. 6)

Teaching Color Separation

The Graphic Arts Technical Foundation (GATF), forecast the need for well-trained people in the printing industry. It indicated that many skilled jobs will be affected by the changes in technology and that better trained people will be needed to match the challenge. One of the areas stressed in the report was color separation (Sullivan, 1981). Simich, Educational Director for GATF, said:

> A few years ago, the major gap between industry and education was the process gap; that is, the emphasis on teaching letterpress for an industry that had drastically changed to primarily lithography. However, a new gap between industry and education is emerging--the technology gap. As computerized, computer-assisted, and/or electronically controlled equipment and devices are introduced, there will be new procedures and new skills to consider. The technology gap can become as great as, if not greater than, the process gap. Education and industry working together can keep that gap from spreading.
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> Industry forecasts have definite implications for education, and teachers of graphic arts/graphic communications should take heed. Teachers must strive to keep abreast of new developments. If the objectives of graphic communications education include interpreting industry to students as well as providing experiences in its processes, procedures, and resulting products, then we, as educators, should convey up-to-date information. (1981, p. 8)

Traditionally, color separation has only been taught in a very small number of schools. But, more educators are recognizing the need and are starting to include it in their curriculums (Dependent Schools (DOD), European Area, 1974). Buendia (1978) found that none of the community colleges or vocational schools in the San Francisco Bay Area taught color separation. Two of the schools contacted indicated that they should be teaching the subject but this was not done because of equipment costs and lack of teacher willingness. Another author stated:

> With the growth of the graphic arts industry in both size and technology, there is a constant need for updating the educational concepts taught in high schools and colleges. . . . To keep their curricula consistent with the ever expanding technology, it seems only reasonable that the next concept to be included in present programs is color separation photography and color printing. (Mann, 1967, p. 1)

In the schools that teach color separation, a major obstacle is the cost of the equipment. To teach color separation, as used by industry, a color scanner is needed. Only ten schools in the United States could be found to have a color scanner (Sullivan, 1981). Almost all of these scanners were donated. Often donated scanners are obsolete, and all are expensive to maintain. (J. Simich, personal communication; January 26, 1984).

The GATF Education Committee stated that the updating of teachers is essential, and color separation was listed as one of the areas most in need (Swartz, 1983). The printing industry wants the training of graphic arts teachers to be up-dated (Rutherford, 1981).

Electronic Color Systems

These systems use a scanner to input the images into a central computer. All the color images and the type for a printing job are stored in the computer. The operator can then manipulate all these images to the desired size and position. These systems have the capability to replace a part of an illustration with another image. As an example, an imperfection on a model's face may be removed electronically to produce an unblemished image. Some of these systems can output directly onto the image carrier, thereby by-passing all photographic processes. The job can also be stored in a computer storage device for later use. The first comprehensive electronic color system on the market was the Israeli Scitex Response system, which listed for one million dollars (Spotlight on Photomechanical Techniques and Trends. 1981; Goodstein & Smiley, 1982).

Systems for Schools

The costs of modern color separation equipment and the complexity of the older photographic systems have prevented most schools from teaching the process of producing color separations. Scanners and other expensive color separation equipment are beyond the abilities of most schools to purchase and are therefore considered to be beyond the scope of this study. Systems within the ability of schools to own and use will be reviewed here.

Mohan and Bell (1977) suggested teaching color separation with a 35mm. camera. The separation filters are placed in front of the camera lens while a still life is photographed four times. While this is not a commercially acceptable method, the authors suggested this method to teach the basic concepts of color separation while avoiding high costs and complicated procedures. They admitted that quality and color correction were sacrificed, but recommended the system as a viable teaching method.

For the past several years, GATF has been concerned with the teaching of color separation, and has developed some methods expressly for teachers. GATF has demonstrated these methods in the summer teacher institutes to help teachers with limited resources teach color separation, without meeting the industry's standards for production.

One method suggested by GATF used othrochromatic film for two of the separations and panchromatic for the other two. Pan film is sensitive to all colors of light. Ortho film is not sensitive to red light. Because of this, red safelights can be used when processing ortho film, but pan film must be processed in total darkness. No color correction was suggested. They recommended making the separation negatives from a color transparency with a contact frame. Most school cameras have quartz-iodine lamps which are unacceptable for color separation. Pulsed xenon, with its more balanced output, is needed to produce color separations on a process camera (Cozart, 1979). GATF no longer recommends using orthochromatic film because of its skewed color sensitivity.

Some color separation systems have been developed for small printing businesses, which also are unable to afford costly and complex systems. GATF now recommends one of these, the Kodak A, M, and B system, for teachers. This system has been used widely as a non-scanner color system. Eastman Kodak Company (1980) provides step-by-step instructions for producing a set of color separations on a contact frame using two silver masks for color correction. This system has three-aim-point control, using a gray scale with three fixed densities. When exposed with the original, the three density patches represent the highlight, midtone and shadow areas of the original. By reading the densities in the area of the mask exposed with the A, M, and B patches, a contrast range and mask number may be calculated for checking the acceptability of the mask (Eastman Kodak Company, 1974). Exposures on both the masks and separation negatives are made by trial and error. Once a film transparency is exposed, developed, and checked with a densitometer, the system recommends whether to increase or decrease the exposure and/or development (Eastman Kodak Company, 1980). Since only general suggestions are given, several attempts may be required to produce each acceptable mask and negative.

In 1980, Kodak introduced the Q-700 exposure computer. The Data Center is a Texas Instruments programmable calculator and printer with a small integrated chip that is placed in the calculator (Kodak Data Module/Q-700DS - Direct Screen Color Programs for the Graphic Arts. 1981). When introduced, the Q-700 was only for black and white reproduction, but Kodak indicated that in the future they would market a programmed chip for color separation (Kodak Introduces Data Center for Simplified Quality Control Calculations. 1980). The Q-700 has an excellent performance record, and presents excellent possibilities for teaching color separation in the school if programmed for color separation.

In the 1982-83 school year, the College of Engineering Sciences and Technology at Brigham Young University awarded this researcher a grant to purchase and test the feasibility of using the Kodak Q-700DS (direct screen) to teach color separation to university students. It was not found to be successful in the BYU laboratory. The Q-700DS requested exposure times which were far too short and development times which were far too long for the production of satisfactory masks. (It should be noted that Kodak recommended this system be used with an expensive mechanical film processor. The processor uses a different developer than the lithographic type developer that was used in a tray for the testing at BYU.) Kodak was unable to suggest solutions to remedy the problems. Thus, the Q-700 was found to be unsatisfactory for successful color separation operations within the limitations of the BYU laboratory.

Statement of the Problem

The contemporary printing industry faces an increasing demand for color printing. This requires properly trained personnel to produce color separations, which are necessary for color printing. The industry uses expensive computerized equipment to control this complex process. However, schools cannot afford currently available computerized color separation systems for in- service training of printing teachers. The purpose of this study was to develop a successful computerized color separation system and to test its effectiveness in in-service training of printing teachers.

Objective

The objective of this study was to create a computer-assisted color separation instructional sequence and to assess its effectiveness in the in-service training of printing instructors. The computer program was written in the Pascal language designed to run on CP/M-based microcomputers. This program is intended to enable the instructors to produce, in a one-day seminar, a set of color separation negatives that meets industry standards. The program is designed to be used with photographic equipment frequently available in well-equipped graphic arts laboratories. The program is known as the Marchant Color Separation System.

Research Hypotheses

The following hypotheses were tested using the Marchant Color Separation System in a one-day in-service seminar:

1. Printing instructors will produce three required silver masks with their mask numbers and highlight-to-shadow ranges matching, within tolerances, the listed aim points.

2. Printing instructors will produce a set of four color separation negatives with densities that match, within tolerances, the listed aim points.

3. Those printing instructors with greater graphic arts photography

teaching experience will produce photographic masks and separation negatives that more closely match the listed aim points, when compared to instructors with less photography teaching experience.

4. Those printing instructors with greater graphic arts photography industrial experience will produce photographic masks and separation negatives that more closely match the listed aim points, when compared to instructors with less photography industrial experience.

5. Those printing instructors with greater microcomputer experience will produce photographic masks and separation negatives that more closely match the listed aim points, when compared to instructors with less microcomputer experience.

The Marchant Color Separation System

The Marchant Color Separation System is a microcomputer program. The system assists the user in producing an acceptable set of color corrected separation negatives by calculating exposure and development times. The system does not require the purchase of expensive equipment; it does use photographic masking for proper color correction. A copyright for the Marchant Color Separation System was issued June 10, 1985.

The microcomputer is especially adept at handling complex mathematical calculations very quickly. For many years, the mathematical calculations needed to control the many exposures required to produce color separations have been published. But, because these calculations were so complicated and frequently not understood by the cameraman, photographic color separations were commonly done by trial and error (Maurer, 1981). The microprocessor is an excellent tool for calculating photographic exposures (Dooley, 1980; Van Arsdell, 1976).

This study investigated the possibility that the microcomputer would save time and supplies, while assisting in the production of color separations. The saving of valuable time and supplies is important to the educators who teach color separation. In the schools, these savings could make the teaching of color separation possible. In other technical teaching areas, such as automotive ignition diagnosis, the microcomputer has already been demonstrated to be a successful teaching tool (Diedrick & Thomas, 1977).

To use the system, the user first exposes and develops one of the separation masks. The aim points on the mask, (highlight, midtone and shadow), are read by placing each aim point of the mask under the probe of the densitometer. The densitometer displays the density numbers, which are then recorded by keying them into the computer. The computer indicates whether the mask is acceptable. If it is not acceptable, the computer lists the exposure and development times which will produce an acceptable mask. The same procedure is followed for each of the other two masks. Then, using the cyan separation mask and a pre-angled contact screen, a halftone exposure test sequence is performed. With the results of the tests, the computer calculates the exposures for the cyan, magenta, yellow, and black printer separation negatives.

The Marchant Color Separation System judges the quality of the photographic color separation transparencies against standards commonly used in industry. The Color Separation Aim Points listed in Table 1 have been selected as the industry standards for the Marchant Color Separation System (Southworth, 1974). (The real numbers are logarithmic densities of photographic film while the integers indicate the percentage of the total area occupied by printed halftone dots.)

TABLE 1

Color Separation Aim Points

Mask Aim Points

For	Cyan	Magenta	Yel & Blk	Tolerance
Mask number	.175	.075	.075	± .05
H-S range	.85	.85	.85	± .05

Separation Negative Aim Points

Area	Cyan	Mag & Yel	Black	Tolerance
Highlight	5	4	0	± 1/2 %
Midtone	65	50	5	± 2 %
Shadow	95	85	60	± 5 %

Aim Points Converted to Film Negative Densities.

Area	Cyan	Mag & Yel	Black
H - Step 3	1.25-1.35	1.35-1.45	4.00 +
M - Step 9	0.17-0.20	0.28-0.32	1.15-1.52
S - Step 16	0.01-0.05	0.02-0.10	0.10-0.26

System Development

The primary methodology used in this study may best be described as educational research and development. Though research and development is relatively new in education, established procedures follow the pattern of development, testing and revision of an educational product. As an introduction to developmental research, Borg and Gall wrote, Educational research and development . . . appears to be the most promising strategy we now have for improving education (1983, p. 772).

In 1982, Cheng published a microcomputer program which converted the exposure factors found in E. I. Du Pont de Nemours and Co.'s *The Contact Screen Story* (1972) for exposing halftones. This program was found to work well when exposing black and white, continuous tone, reflective copy (photographs). Though they are more complex in many ways, color separation negatives are actually halftones which require the same exposures as black and white halftones. An understanding of the differences between black and white halftones and color separation negatives led this researcher to prepare and validate a microcomputer program for exposing continuous tone, full-color transparencies.

Color separation negatives are more complex than black and white reproduction in several ways. Separation masks are exposed and developed differently than black and white halftones. These masks are used in the light path when exposing separation negatives, therefore exposures must be adjusted for the mask densities. The separation negatives do not all use the same mask, thus adjustments are required for the different combinations of masks and separation negatives. Each separation negative is exposed with a different color of light through the use of colored filters placed in the path of the light. As the filtering colors vary, differing amounts of light are transmitted. Exposure times must be adjusted to compensate for variations in the intensity of light. Because printing inks are impure, different aim points must be used with the respective separation negatives. Varying the aim points also requires an adjustment in exposures. The color separation process depends upon exposure computations which consider all these interacting variables.

In 1983, after determining that the Kodak Q-700 was not a satisfactory system for teaching color separation in the schools, this researcher undertook to prepare a microcomputer program for color separation. The system was configured to meet the objectives of this study--a system which would produce industrially acceptable separation negatives within the limitations commonly encountered in a school laboratory.

System Method

Direct color separation was selected in opposition to indirect color separation which requires more steps, film, and exposures and which is therefore more costly in terms of time and supplies.

Equipment

The Marchant system was tested using a contact exposure frame instead of the more popular process camera. Avoiding cameras avoided three problems:
1. Most schools do not have pulsed xenon lights on their process cameras, yet

these lights are necessary for color separations because of their color temperature. 2. Camera back masking is more complicated than masking using a contact system. In camera back masking, the mask must be exposed in the same physical location it will be in while the separation negative is being exposed. During the exposure of the separation negative, the film will be against the camera back, at the focal plane. In contact with this film is the contact screen. The mask is located between the screen and the camera lens. As the image is reflected off the copy, it is inverted through the lens and fans out in size until it reaches the focal plane. When the image reaches the focal plane, it is again in focus and is at the desired size. The image is not in focus and is not at the desired size at the location of the mask. 3. Each separation negative must be exactly the same size to be printed in registration on a printing press. The cameras typically found in schools do not have the precision measurement controls to allow the exposure of one negative, the adjustment of the camera for another job, and the readjustment back to precisely the same settings used in producing the first negative. Because students could not complete a set of separation negatives in one school period, this procedure would require the camera percentage or size adjustments to remain untouched during the entire process. This restriction is not functional in school settings.

The contact method does have one major problem. The size of the original cannot be changed when using a contact frame. This requires a transparency which is the desired size of the final printed product. The transparencies for this study were prepared with a 4 X 5 camera. A 4 X 5 inch colored transparency is small enough to be cost effective, yet large enough for publication.

Film Development

For the masking film, this study used Kodak Pan Masking Film. The separation negatives were produced using Kodak Pan Film. Both films are commonly used in industry.

Printing companies normally develop these films in expensive lithographic type mechanical film processors which cost approximately $30,000. Most schools manually process their film in trays. Film processors are faster than processing in trays, and they provide better control of the variables of development which are critical in color separation: time, temperature, agitation, and freshness of developer. At the beginning of this study, tray development was used. The temperature of 20 degrees C., ± 1/4 degree, was maintained with a temperature controlled sink. After a series of tests, it was determined that a new batch of developer was necessary for each sheet of film. A decrease in density was noted on the second sheet of film developed in a tray of developer. Agitation was controlled by a mechanical tray rocker.

During the study, the film development process was changed from tray development to rapid access development. Rapid access development uses a film processor which costs much less than the lithographic type processors (approximately $4,000). The rapid access developer was created for phototypesetting papers and contact grade films. For the films used in this study, the manufacturer does not recommend development in this type of process. The rapid access developer is a one part continuous tone type developer which was found in this study to work well with the pan masking film. By adjusting for the large fringe (non- printable part of a halftone dot), created by the rapid access developer, it was determined that acceptable separation negatives could be obtained using the rapid access developer. The control provided by the rapid access processor was found to outweigh its disadvantages.

To provide color correction for process color printing inks, a masking system was necessary. Richard Warner, GATF color separation specialist, recommended that color separations be made with three masks (personal communication, 1982 GATF Advanced Teacher Institute). Kodak's direct system uses two masks. Since each different separation negative requires different aim points, they each need different exposures. Normally all halftones require two exposures--the main and the flash. The main exposure is used to place the correct size of dot in the highlight, and the flash to establish dot size in the shadow. In addition to the main and flash exposures a highlight bump exposure may also be used. The bump can adjust the mid-tone dots. This exposure is very powerful, thus very short. When performing the bump exposure, the main exposure must be shortened and the flash duration lengthened (E. I. Du Pont de Nemours and Co., 1972). The cyan negative midtone dot size is appreciably different than the yellow and magenta. Normally, this difference is adjusted while exposing the cyan negative with a bump exposure. The bump exposure is difficult to control and most difficult to program (Archer, 1977). The Marchant system produces three separation masks. The additional mask is used to produce the cyan separation negative. The cyan mask in the Marchant system requires a different mask number, which adjusts the cyan midtone without the use of a bump exposure. By making this third mask the Marchant system eliminated the use of all bump exposures.

To control the Marchant system, a gray scale is exposed with the color transparency. This becomes a quality control device. All film transparencies are checked by reading the densities of the film where the exposing light passes through the gray scale. The Stouffer 21 step sensitivity guide was used as the system's gray scale. On the gray scale, step 3 was selected to represent the highlight of the original, step 9 the mid-tone, and step 16 the shadow.

Three point control of color separations was developed by Kodak. Stouffer's densities at steps 3, 9 and 16 do not precisely match the A, M and B areas of Kodak's three point gray scale. Thus, the mask number and the highlight to shadow range of the Marchant system do not match the Kodak system. The aim points for the mask numbers and H-S range were adjusted to compensate for these differences.

Microcomputer Program Development

The program was written using the TeleVideo microcomputer with the CP/M-80 operating system. Because of the researcher's programming experiences, the high level language, JRT Pascal, was selected for the program. The first language used was JRT Pascal version 2.0, available from JRT systems in California. When JRT developed version 3.0, the program was rewritten to take advantage of the up-dated version. During the field test, a teacher in-service seminar, a serious file handling error was discovered. The error was found to be due to a weakness of the JRT language. By this time, JRT Pascal had become the property of Ellis Computing, which markets the Pascal under the name *Nevada Pascal*. Nevada Pascal was found to be version 4.0 of JRT Pascal. Once the program had been rewritten for this version, the file handling error was eliminated. The program has since been adapted to Turbo Pascal which is a popular pascal language in universities. The program has also been adapted to run on IBM microcomputers.

The program was developed in the same order as the steps in the color separation process: separation masks, exposure tests for the separation negatives, the production of the four separation negatives, and the evaluation of the negatives with the possibility of replacing non-acceptable negatives. Early in the program development, the program became too large for the computer's memory. The program was then divided into external programs, separate program files, each of which was automatically loaded into the computer's memory as needed.

Subsequently, the main program is basically a menu which controls the operation of the program in response to user selection. When a user first activates the program the menu appears and gives these choices: SM for Separation Masks, SC for Separation Calibrations, SN for Separation Negatives, CN for Check Negatives, and EX to Exit. The separation calibrations and separation negatives sections are used to determine exposures for the separation negatives. Also built into the main menu is the creation of an external data file which stores all data which will be needed by another part of the program.

Separation Masks

This first section of the program was written to evaluate the separation masks and then to recommend new exposure and development times if a mask is not acceptable. Once an acceptable set of masks has been produced, those times can then be used as a starting point for the next job. Though the exposure factors for halftones have been in print for a long time, exposure factors were not known for the masking film. In halftones, the density curve, which is the relationship between the highlight, midtone and shadow areas of the original, is controlled by the main, bump and flash exposures. Because a mask is continuous tone and not a halftone, shadow flash and bump exposures cannot be used to control the density curve. The density curve in a mask is controlled by varying the development time as well as the exposure time. Since factors for exposure and development times were not available, a major part of the research was the determination of a workable set of factors. These were found through a series of exposure and development tests.

The two numbers which are used in the system to determine if a mask is acceptable are the highlight to shadow range (H-S range) and the mask number. The H-S range is found by simply subtracting the density of the shadow from the highlight. The difference between the densities of the number 3 and 16 steps of the gray scale is found on the mask. The formula for the mask number is (M-S)-(H-M), where M is the midtone density. It was known that the H-S range is primarily affected by the development time. An increase in development time will increase the H-S range, but it will also tend to increase the mask number. An increase in the exposure time will increase the mask number, but it will also tend to increase the H-S range. If the development or exposure times are decreased, the H-S range and mask number will decrease.

A series of tests was performed to determine multiplication factors to be used in the program. First, five masks were exposed, at progressively longer times. They were all developed for a specific length of time. Then five more masks were exposed for identical times but developed at five progressively different times. The resulting mask numbers and H-S ranges enabled the researcher to plot two mask number curves and two H-S range curves. These curves were then interpolated to determine how much the exposure and development times affected both H-S range and mask number. The resulting mathematical factors were listed with increments of 0.01 density. Twenty increments above and below the desired H-S range and twenty steps above and below the desired mask number were then written into the program.

The masking section of the program first presents the user with a menu of the three masks and asks the user to press one number to select the mask to be evaluated. Next, the microcomputer asks for, and the user keys in, the exposure and development times for the mask being evaluated. Next, the densities of steps 3, 9 and 16 are typed into the computer. The program then selects the appropriate aim points, figures H-S range and mask number, and checks them against the aim points. If the H-S range or the mask number is not within tolerances, the mathematical computations are performed to determine new exposure and development times. The program then prints to the monitor, and at the same time sends to a line printer all the information which was entered, the H-S range, mask number, and whether the mask was acceptable. If the mask did not match the aim points, new exposure and development times are also listed.

As an example of a cyan mask: The user would first select mask number one which the program uses to appropriately title the computer output, store the densities into memory as densities of the cyan mask (variables C.H1, C.M1, and C.S1), and establish the mask aim point as 0.25, with 0.20 the minimum and 0.30 the maximum acceptable. All three masks use the same H-S range aim points: 0.85 as ideal, with 0.80 the minimum and 0.90 the maximum acceptable. The program then figures the H-S range and mask number. As an example: if step 3 had a density of 1.30, step 9 a density of 1.09, and step 16 a density 0.55, the program would figure the H-S range as 0.75 and the mask number as 0.33. This mask number, which is 0.03 too high, would have the exposure time multiplied by the factor of 0.85 which would decrease the exposure time. With an H-S range of 0.75, the program would establish that it is 0.05 too low. This would cause the development time to be multiplied by 1.11 and would multiply the new exposure time by 0.91 to adjust for the increase in development time. If the original exposure time was 30 seconds, the new exposure time would be 23.2 seconds. With an original development time of 20 seconds, the new development time would be 22.2 seconds. Because the cyan mask is exposed with two filters, the program would also determine that 3/4 of the new exposure be with the 23a filter and the remainder with the 58 filter.

Separation Calibrations

The first step in finding the exposures for the separation negatives is to select from the main menu the SC section for separation calibrations. This sends the user to the CAL or calibration procedure. Other than the main program, all other sections in Pascal are called procedures or functions. The CAL procedure lists another menu to select from: GS-to enter the 21- Step Gray Scale Densities, BM-to enter results from the Basic Main Exposure Test, SF-to enter the results of the Shadow Flash Exposure Test, and EX-to Exit back to the main menu. Before any calibrations can be made, the program must know the densities of each step of the gray scale being separated with the color transparency, so GS is selected.

GS simply asks for, and stores one at a time, the densities of each step of the gray scale. These densities are stored in the data file which means they only need to be entered once. These numbers provide the basis for adjusting exposure times.

BM is the next section in CAL to be used. A basic main exposure test is made by exposing a sheet of film using only the main exposure. For this test, the contact screen is placed over the pan film. The jig sheet is place on top of the contract screen. The jig sheet carries the color transparency and gray scale. The mask is placed on top. The basic main exposure test is exposed as a cyan separation negative. This means using the cyan mask and exposing with the 23a red filter. The cyan is used because it is the most important and is produced first. After the film is exposed, it is developed. All separation negatives are developed for the same length of time. The BM section first asks for the exposure time used in the test. Then the user is required to input the densities of all 21 steps of the gray scale which were exposed onto the pan film. The test negative is now a halftone. The densitometer is adjusted to read the density of the halftone dots. The density of each step is read from the basic main test exposure negative and is entered into the computer.

Densitometers can be used to determine the percent of dot size. As an example: if the densitometer reads 0.30, only half of the light is transmitted through the halftone which means the dots cover 50 percent of the area. However, to be accurate, the densitometer must first be adjusted to compensate for the just- non-printable (JNP) dot. Dots called ghost dots appear in the extreme shadows. These dots will register on the densitometer, but they are too thin in density to hold back the exposing light when the printing plate is made. The JNP dot is selected from a contact exposure, made from a film negative with varying sizes of shadow dots onto high quality contact paper. To adjust for the JNP dot, the densitometer is set to 0.00 at the dot size which is determined to be the just-non-printable dot.

After all 21 steps are entered into the BM section of the program, the computer finds each of the important separation negative aim points. The aim point for the cyan highlight dot is a 5 percent dot. This is translated into a density of 1.30. At this point the program moves to the FindD function. FindD takes the aim point density, such as 1.30, and locates its theoretical location in the halftone. Chances are low that any one step would be exactly 1.30 in density; the program estimates its location between the step just above and just below the aim point. The density at this location in the original gray scale is now determined from the densities stored in the data file. This density number will allow the computer to determine how much exposure is necessary to produce the aim point size of dot in the desired step. These five densities are stored in the data file. From these densities, the main exposure times for each separation negative will be determined, along with the screen range which is necessary to figure the shadow flash.

Next, the SF section of CAL is used. Two sizes of dots are used as shadow dot aim points. The SF section determines how much exposure is need for each. A flash exposure test is made by placing a fresh sheet of film under the contact screen and giving it an exposure. (The jig sheet and masks are not used.) Also, a neutral colored light is used. After this film is developed, it will have only one size of dot in it. The density of test film is entered into the computer along with the exposure time. The program now calculates and stores the exposure time for both sizes of shadow dots. These times are called the basic flash exposures. If either the basic main exposure test or the flash exposure test is over-exposed or under-exposed to the point where the results cannot produce all the information needed, the program will instruct the user to redo the test and will suggest an exposure time. After running SF, the program now has sufficient data to figure the exposure times for each separation negative.

Separation Negatives

Returning to the main menu, the user can now select SN for separation negatives. This routine sends the data through hundreds of calculations to determine the exposure times for each separation negative. This command requires no additional data input from the user, but all the previous sections of the program need to have been used and their data stored before the SN computations are performed.

After the user types SN, the program jumps to the NEGS where it first figures the main exposure for the cyan separation negative. It starts by finding the difference in density between the number 3 step of the original gray scale, (where the desired 5 percent highlight dot is wanted), and where that size of dot was found on the basic main exposure test negative. An exposure factor is needed to convert the basic main test exposure into the main exposure for the separation negative. To explain: The 5 dot is wanted in the step 3 area. Using the densitometer we may find that the density of that step on the original gray scale was 0.35. But, after the basic main exposure test, say of 30 seconds, the 5 dot was found in the area to correspond with the 0.45 area of the gray scale. The difference between 0.45 and 0.35 is -0.10, whose anti-log is 0.79. Using 0.79 as a multiplication factor with the exposure time of 30 seconds ($0.79 \times 30 = 23.7$) a new exposure time of 23.7 seconds is obtained. This shorter exposure would reduce the density enough to lower the 5 dot into the 0.35 density area.

A logarithmic formula calculates an exposure factor, which is the anti-log of the film density. The exponent of a logarithmic number is the anti-log. However, the pascal EXP function reports the exponential with a natural logarithmic base, whereas this program required logarithms based on 10 (common logarithms). Dividing the logarithmic number (density) by 0.4343 before executing EXP, converts it to common log (Knecht, 1983). Thus the following formula was used: Factor EXP(density difference / 0.4343).

The anti-log formula is used to determine the main exposure time for the cyan separation negative. However, it was found that the accuracy of this exposure varied. It was determined that an adjustment was required to compensate for the density of the mask. The cyan mask was used in the light path during the exposure of the basic main exposure test. If the 5 dot was found in any area but step 3, the density of that step in the mask would not allow the above formula to be accurate. It was thought that a basic main exposure test without the mask would create too large an exposure adjustment for the program to be accurate. The solution to this problem was the writing of the MAdj (Mask Adjustment) function. Using the densities of the masks stored in the data file, MAdj would interpolate the density between step 3 and the step in which the desired dot size was found. Procedure NEGS uses this density difference and the anti-log formula to readjust the main exposure. NEGS now can determine the main exposures for the magenta, yellow and black separation negatives.

Calculating the main exposure times for the other separation negatives is similar to computations for the cyan negative. Each is computed from the same basic main exposure test negative. For the magenta, a different highlight dot is needed. This time the exposure factor is calculated from the difference between the gray scale step 3 density and the density where the 4 dot was found in the test negative. The magenta also uses a different mask, which requires an adjustment of the exposure to compensate for any differences in density between the mask used in the exposure test and the mask to be used with the magenta separation. The magenta separation uses a 58, green filter, which has a different filter factor than the 23a used in the test. With these adjustments, the main exposure for the magenta separation negative is stored into the computer's memory.

Next, the main exposure for the yellow separation negative is determined. The yellow separation is very similar to the magenta. The only differences which need to be adjusted for are the use of a different mask and a different filter, (47b).

The last main exposure to be figured is for the black separation negative. The black negative is heavily exposed. A 5 dot is the aim point, but is to be placed in step 9, not in step 3 as with the other separation negatives. This exposure uses the same mask as the yellow and uses no filters. The black separation has only one exposure, the main. With the black main exposure calculated, the flash exposures are now found for the other three separation negatives.

The flash exposure for the cyan separation is found by first determining the excess density, the difference between the screen range (the difference between the highlight and shadow dots), and the copy range (where those dots were found in the test negative). If the excess density is not greater than 0.0, no flash exposure time is generated and the separation negative receives only a main exposure. The aim points in relationship to flash exposure time are calculated from the shadow flash exposure test. A separation flash exposure is a percentage of the basic flash exposure, based on the amount of excess density. This percentage is found with another function labeled Shadf (Shadow flash). Shadf is simply a listing of excess densities with the appropriate percentages assigned. Shadf assigns to the procedure NEGS a percentage which, when is multiplied by the basic flash exposure time, obtains the correct shadow flash time for the cyan separation negative.

Since the magenta and yellow separation negatives have the same highlight and shadow aim points, their flash exposures are figured together. They do use different masks, but masks are not used during the flash exposure. However, it was found that a different screen range is created with each colored filter. After further experimentation, factors were developed to be used in the program at this point to correct for the differences. This procedure completes the calculations of exposure times.

The last action invoked by procedure NEGS is a listing to the screen and to the line printer of the exposure times and helpful information for each separation negative. Along with the exposure times, the NegData procedure lists the following: which separation negative the listing is for, exposure filter, development times, and screen angle. Also illustrated are positions of the mask, jig sheet, contact screen and the new pan film for both main and flash exposures. Then, the program returns to the main menu.

The user can now take the information provided by the computer and use it to expose and develop each of the separation negatives. If the user has accurately completed all steps required by the program, and if all exposure and development variables are the same as when the tests were made, the user now has the exposure times which will provide a set of separation negatives with acceptable aim points.

Check Negatives

The CHECK procedure will check each separation negative to find if it meets the aim points. If not, it will calculate new exposure times. This part of the program is activated by typing CH, for Check Negatives, at the main menu. CHECK is an independent part of the program; it requires all necessary data to be entered from the keyboard. It first asks which separation negative is to be checked. For the cyan, magenta and yellow separation negatives, the program requests the densities of steps 3 and 16 of the negative being checked. With the black, only step 9 is checked. If the checked separation negative is within tolerances, the microcomputer indicates that the negative is acceptable and the negative can be prepared for printing.

If the checked separation negative is not acceptable, CHECK treats the negative as if it were a test negative to determine the exposure times which would provide an acceptable negative. At this point, the program not only asks for the times of the main and flash exposures but also for the densities of all 21 steps. The FindD function is then accessed to determine the location of the proper aim points. Then the anti-log main exposure formula is used to adjust the main exposure. Next MAdj, is used to adjust for differences in the mask density. This provides for the main exposure time. The Shadf function is used for determining shadow flash time. Finally, CHECK uses NegData to list the results.

Auxiliary Programs

During the study, two additional routines were added to the program. They are listed on the main menu as auxiliary programs. DBT, debugging tool, lists to the screen all data stored in the external data file. This allows for a check of all data. Originally, the program created only one external data file, which was erased when the next job was entered. The program was changed to give the user the ability to create many data files, one for each job. When the user starts the program, a job identification is required. This will create a new data file if one does not exist by the name given. The user can change the job identification by typing CH and entering a different name. This not only allows the comparison of various jobs but allows the user to be working on more than one job at a time. This section of the program was written into the main section of the program as a part of the main menu.

One additional change requested by the people who tested the program was a command to abort the process of entering data if an error had been entered. At various points in the program, the user is requested to enter 21 density numbers. In earlier program versions, if a user entered an incorrect number, all 21 numbers were still required before the sequence could be repeated with the 21 correct numbers. Now, the program checks every density. If the number 9 has been entered, the program will abort back to the main menu. This was found to relieve some of the frustration of data entry.

Pilot Test

The program was pilot tested September 22, 1984, when a teacher in the Department of Industrial Education at Brigham Young University used the system to create a set of separation negatives. All problems observed during the pilot test and all suggestions of the teacher using the system were addressed by the researcher. Both the program and the user manual were revised to accomplish the improvements.

Field Test

The Marchant Color Separation System provided the content for an in-service seminar for printing teachers held from 9 a.m. to 5 p.m., on Saturday, September 29, 1984.

Population and Sample

University and college teachers of printing from the intermountain west, and high school teachers of printing from Utah, comprised the field test population.

The seminar was planned to coincide with The Mountain States Industrial Arts

Conference which was held in Utah. The conference includes industrial arts teacher educators from the states of Arizona, Colorado, Idaho, Montana, New Mexico, Utah and Wyoming. Invitations were sent to all twenty printing teachers from these states who were listed in the *Industrial Teacher Education Directory* (Dennis, 1984), or the *Technical Schools Colleges and Universities Offering Courses in Graphic Communications* (Education Council of the Graphic Arts Industry, 1983).

The list of high school teachers invited was taken from the *Utah Industrial Education Personnel* (Grover, 1984). Ten of the twenty- five printing teachers listed in the directory were invited. These were the teachers considered by the researcher to be the most outstanding high school printing teachers in the state.

Invitations to the teachers were sent August 27, 1984. Ten respondents, three college printing teachers and seven high school printing teachers, indicated an interest in attending the in-service seminar. On September 25, 1984, a letter was sent to the potential attendees to thank them for their interest and remind them of the date, time and length of the seminar.

The one college printing teacher and seven high school printing teachers who actually attended the in-service seminar were assigned to three working groups, based upon the order of their confirmations to attend. At the beginning of the seminar, the grouping assignments were modified to adjust group sizes when two anticipated participants did not arrive.

Procedures

The researcher gave the participants an introductory explanation of the field test task, the production of a set of separation negatives using the Marchant Color Separation System. Each group chose a leader and each group member accepted responsibility for one mask and one separation negative. Each subject was responsible for either a cyan, magenta, or yellow mask and for the corresponding separation negative. The black separation negatives were assigned as shared responsibilities for the members of the groups.

Prepared jig sheets, each containing two 4x5 color transparencies and the 21 step gray scale, were issued to the groups. The group leaders were asked to label and save all sheets of film and microcomputer printouts. A system user manual with step-by-step procedures was provided to each subject.

The researcher provided a brief introduction into the use of the darkroom equipment: contact frame, electronic timer, film punch, and film processor. Each subject practiced using the film punch on an exposed piece of film with the lights on. Individual sheets of film had been placed in light safe folders with only one sheet per folder. The researcher also explained the use of the densitometer.

Each group was assigned a microcomputer with an attached printer. The use of the microcomputer was briefly explained at the beginning of the seminar. The subjects within a group assisted each other in reading densities and typing data into the computer. All the subjects became experienced with the use of the computer as well as the darkroom activities.

The morning session was used for producing the masks. The subjects started with the suggested exposure times printed in the manual to expose the masks. First, the cyan masks were attempted, then the magenta, and then the yellow. Since only one darkroom was available, and since only one group could use the darkroom at a time, the groups were rotated through the darkroom.

During the afternoon session of the seminar, the researcher explained the procedures for the basic main exposure test and the basic flash test. He also demonstrated how to use the mask and contact screen to expose the separation negative. The groups then proceeded with these tasks.

At the conclusion of the in-service seminar each teacher completed an evaluation sheet. One part of the evaluation sheet asked the subjects to list the number of years of experience they had in graphic arts teaching, graphic arts photography in industry, and work with microcomputers. The subjects were also ask to rank on a scale from 1 through 9 their estimates of their competencies in each of the three categories.

The subjects were ranked for teaching experience by the number of years taught. Three subjects listed 12 years of experience. Since 12 was the median number of years taught and the hypothesis test required division of the group at the median, these three were individually ranked based on the means of their ratings of teaching competence and photography teaching competence.

The subjects were ranked on industrial experience by the number of years they indicated they had worked in the graphic arts industry.

The subjects were ranked on microcomputer experience by the number of years they indicated they had used a microcomputer. Three subjects listed 0 for their microcomputer experience.

The field test subjects gave a high rating to the seminar; however, some problems were observed. The most common problems were not directly linked to the microcomputer program. The two most common problems were punching the film incorrectly and using the wrong mask. The rotation of groups through the one exposure station in the darkroom was a minor problem.

One major problem became evident: though the groups had been successful in producing the mask negatives, none of the groups produced a set of separation negatives which met the aim points. All separation negatives were underexposed. After the seminar, it was discovered that the program had created three data files instead of storing all data in one file. The program was to store data into a file named DNums.dat. However, two additional files were also created, DNums.ddd and DNums. Each group of subjects used a different microcomputer, but each group experienced the same problem. The computer had not stored the data of the masks and the data from the exposure tests in the same file. Without access to the mask densities, the program computed separation negative exposures that were not adjusted for the amount the light that was decreased or filtered by the densities in the masks. This explained why all the separation negatives were underexposed. The problem was subsequently resolved by replacing the JRT Pascal version 3.0 with Nevada Pascal (JRT version 4.0).

Operational Field Test

Since the Marchant Color Separation System was revised after the field test with the experienced teachers, further testing of the system was needed. No other sample of experienced teachers was available, so the system was used in an operational field test with university students in a relevant course. Students in the Process Camera Photography class held at Brigham Young University during the 1985 winter semester served as subjects for operational field testing of the instructional sequence. This course covers the basics of printing photography: line work, contact printing, halftone photography, and color separation. This class used the Marchant Color Separation System for its introduction into color separation.

The thirteen students in the class were assigned to three working groups, with four or five students in each group. The researcher introduced the students to the system, then provided four, two- hour class sessions for its use. Except when a student made a procedural error by using the wrong mask or filter, each mask from every group met the aim points by the second attempt. The first attempt used the suggested exposures given by the instructor. There were five procedural errors while producing the separation masks; three of these were made by group D with their magenta mask.

With the exception of one cyan color separation negative, and one black separation negative, all separation negatives were acceptable on the first try when procedures were followed. Since the one cyan separation negative which did not met the listed aim points was only 0.02 density out, the participants did not consider it necessary to repeat the procedure for its production. The black separation negative was acceptable on the second try, which was based on new numbers from the computer. Six procedural errors were made during the production of the separation negatives: four times the wrong mask was used, once the wrong screen angle was used, and once the electronic timer was set for the wrong exposure time.

Since the Marchant Color Separation System worked effectively with university students encountering color separation procedures for the first time, the system was considered to be adequately developed to be used for instructional purposes in the schools and for in-service seminars for experienced teachers.

Tests of Hypotheses

Hypothesis 1

Hypothesis one stated: Printing instructors will produce three required silver masks with their mask numbers and highlight-to- shadow ranges matching, within tolerances, the listed aim points. The participants from both the field test and the operational field test provided data for testing this hypothesis. The data support the hypothesis. Only one subject had a mask which was not within the aim points. The students (Groups D, E, & F), with no previous experience in color separation were just as successful in producing masks which met the aim points as were the teachers (Groups A, B, & C).

Hypothesis 2

The second hypothesis stated: Printing instructors will produce a set of four color separation negatives with densities that match, within tolerances, the listed aim points. A problem with the programming language prevented the subjects in the field test from producing separation negatives with acceptable results. As an alternative, results of the operational field test were substituted for the unacceptable data produced during the field test. The data support the hypothesis.

Hypothesis 3

Hypothesis 3 stated: Those printing instructors with greater graphic arts photography teaching experience will produce photographic masks and separation negatives that more closely match the listed aim points, when compared to instructors with less photography teaching experience. Because of the program problem resulting in unacceptable separation negatives, only the results of the masks could be used in testing hypotheses three, four and five. Subjects were ranked in order according to experience. Chi-square was calculated to test this hypothesis. To accept the hypothesis with 1 degree of freedom at the 0.95 level, a X^2 of 3.841 was needed. The calculated chi-square was 1.143, which did not attain this level. The hypothesis is rejected.

Hypothesis 4

The hypothesis stated: Those printing instructors with greater graphic arts photography industrial experience will produce photographic masks and separation negatives that more closely match the listed aim points, when compared to instructors with less photography industrial experience. The subjects were ranked based on their industrial experience. Chi-square was calculated to test this hypothesis. To accept the hypothesis with 1 degree of freedom at the 0.95 level, a X^2 of 3.841 was needed. The calculated chi-square was 1.143, which did not attain this level. The hypothesis is rejected.

Hypothesis 5

Hypothesis five stated: Those printing instructors with greater microcomputer experience will produce photographic masks and separation negatives that more closely match the listed aim points, when compared to instructors with less microcomputer experience. The subjects were ranked based on their microcomputer experience. Chi-square was calculated to test this hypothesis. To accept the hypothesis with 1 degree of freedom at the 0.95 level, a X^2 of 3.841 was needed. The calculated Chi-square was 1.143, which did not attain this level. The hypothesis is rejected.

Findings

It was found that printing teachers could produce silver masks which met aim points used in the printing industry. It was also found that the university students, who had no previous experience in color separation, were as successful as experienced teachers in the production of silver masks using the Marchant Color Separation System. Separation negatives which met aim points used in the printing industry were produced by the application of the Marchant Color Separation System in the operational field test.

When field test results were compared on the basis of experience, neither graphic arts photography teaching experience, graphic arts photography industrial experience, nor microcomputer experience was found to be a determinant of success in the use of the Marchant Color Separation System. However, all teachers in the field test had experience in phototypesetting, a process quite similar to the operation of a microcomputer.

Conclusions

It is concluded that the Marchant Color Separation System is sufficiently sensitive and accurate to produce industrially acceptable color separations within the limitations of the experimental conditions in this research. Previous experiences in teaching, printing, working in the printing industry, performing color separations, or using microcomputers are not prerequisites for successful production of color separations when using the Marchant Color Separation System.

Recommendations

It is recommended that the Marchant Color Separation System be tested in other educational settings. It is also recommended that the system be tested in commercial printing establishments to ascertain whether the system has direct application in the printing industry.

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