New Fujifilm Image Intelligence: The Next Generation of Automatic Image Quality Optimization

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Abstract

Digital image-processing technology has been a focus of Fujifilm research for many years, and has been incorporated into various photographic digital printing systems. The proprietary algorithms, known as Fuji Image Intelligence, automatically adjust the images to produce optimal quality. New advancements in Fujifilm's Image Intelligence software utilize innovative, advanced technology that will include professional image correction features. These include face extraction information for skin tone optimization, color-fitting technology, noise reduction, and many other enhanced features. These tools will be utilized for photographic printing, graphics arts, and medical imaging diagnostics.

Introduction

The growth of digital photography has created many new challenges for the printing and photofinishing industries. Fujifilm has been instrumental in achieving consistent, high quality output from its Frontier system of digital photographic printers for many years, and established an excellent reputation with the superiority of its film scanners. A key feature to this closed-loop photofinishing system has been the development of Fujifilm's Image Intelligence, which is an integration of all of the image analyses, evaluation and processing technology that Fujifilm has amassed over the years. In a constantly-evolving environment at Fujifilm, new technologies have recently been incorporated into our systems that reproduce the image processing that humans carry out.

History of Image Correction

Analog photographic printing technology became more sophisticated during the 1980's, when high speed photofinishing equipment was developed by the major photographic equipment manufacturers, including Fujifilm. This scanning technology involved the use of optical sensors that measured the red, green, and blue response of light transmitted through the film base and image dyes. Basic computer algorithms then analyzed the data and applied overall corrections to the exposure, usually by varying the filtration and exposure settings. The difficulties of scanning color negative film, which include film-base color differences, processing effects, non-linearity of color (dependant on exposure), and emulsion variations, combined to make the process very difficult as a means to facilitate consistent quality. Initially in photo labs, film had to be sorted by manufacturer and film speed, and then printed on specific printer "channels" optimized for that particular film type. As the technology improved, more sophisticated image analysis allowed whole-roll film scanning. The introduction of film-edge bar coding on 135 film also helped automate the printing process. Sophisticated film emulsion technology also includes ways to optimize skin tone reproduction, neutral balance, and color reproduction, and a recent development by Fujifilm also allows optimization for mixed lighting with the use of 4th Color Layer Technology.

With the introduction of digital imaging, and the remarkable growth of digital camera use, the technology has had to become even more advanced. From a printing perspective, electronic analysis of images has the potential to analyze every individual pixel, thereby allowing more sophisticated image adjustments. In an analog system, the image processing is handled by the camera exposure, film, printer technology, and photographic paper characteristics. In the world of electronic capture, much of the image processing must be handled in-camera and during the pre-printing stage. The result has been a workflow which is sometimes more laborious for the photographer, in order to obtain acceptable prints of the images. Although this workflow can, at times, be seen as allowing more control for the photographer, it can also result in additional work that is seen as a burden for some.

History of Fujifilm Image Intelligence

Born out of Fujifilm's longstanding imaging expertise and the new, powerful, generation of digital hardware and software, Image Intelligence has proven to be a valuable innovation. The effort began in the era of analog printing, and in this R&D track, Fujifilm has built up a massive image database and developed a host of sophisticated image processing software technologies. The original digital photofinishing systems from Fujifilm, known as Frontier Digital Lab Systems, were designed to scan and analyze film, and send digital data to a RGB laser exposure device to produce images on photographic paper consisting of cyan, yellow, and magenta dyes. The system also allowed an operator to apply manual image corrections based on the imagery viewed on a CRT display. This closed-loop system worked most efficiently in a sRGB color space workflow, because the image on the CRT display and the printer output both fit predominantly inside this color gamut. A sRGB workflow was maintained along with the progression to digital camera file printing with the Frontier system, because this produced the most efficient workflow that would handle a large volume of files, while producing the highest overall quality with silver-halide photographic paper output. Most of the internal image processing performed in digital cameras had produced images in the sRGB color space, and the Frontier printing system transformed the image data from sRGB to the Frontier laser exposure data using internal 3D Look Up Tables optimized for the lasers, chemistry, and paper characteristics used in that device. While new software has been developed for the

Fujifilm Frontier professional environment to work in a more sophisticated environment that utilizes a color-managed workflow (based on the color profile system developed by the International Color Consortium, or ICC), involving conversion from various image file color spaces to the device output space of the Frontier printer; this has not negated the requirement for optimizing image data in order to produce a large first-run, high-quality, output system. Therefore Fujifilm has continued to advance the development of Image Intelligence technology to provide a high-speed, high-quality, solution. Fujfilm Software, located in Silicon Valley in the U.S. (created in 1997 to conduct R&D work in the digital imaging field), developed core technology that is used for equipment used in the digital imaging business. This technology development, along with researchers in various divisions at Fujifilm headquarters in Japan, helped to spur the development of the latest version of Image Intelligence.

Features of New Fujifilm Image Intelligence

The latest Image Intelligence uses technology such as face extraction information and scene identification, to not only optimize the image as the photographer intended, but also provide consistency between frames of similar scenes, which has always been difficult to produce. When determining overall quality of pictures that include people as the subject, skin tone accuracy is the dominant factor that is generally used as a reference. If the color rendition, density, smoothness, detail, and sharpness of skin tone are not correct (as seen by the viewer), the image is perceived to be inferior. It is for this reason that Fujifilm emphasizes facial feature detection as a basis for image correction in the new generation of Image Intelligence. Integrated with other advanced features, such as Hypertone, Hyper-sharpness with grain control, and noise reduction, this technology is a state-of-the-art advancement in consumer and professional imaging, as well as medical imaging and graphics arts.

In photographic digital imaging, Fujifilm Image Intelligence utilizes two sets of software technologies, including Scene Analysis Algorithms, which analyze shooting conditions in addition to the subject, and Image Expression Algorithms, providing further corrections to the analyzed scene. Image Intelligence uses the power of processing software that draws on a large image reference database that Fujifilm scientists have amassed over the years. This library represents nearly every conceivable photographic setting, angle and situation. By using this library, engineers can accurately determine photographers' objectives, appraise lighting conditions, and build corrective measures into the software.

The Scene Analysis Algorithms automatically analyze photographic conditions such as light source, exposure, and lighting direction, in addition to the subject, by using facial detection. Based on this analytical data, in conjunction with the image database, the best method for adjusting the skin and scene areas is determined. DCR (Hypertone) technology optimizes density in any part of the image to achieve density transitions that are more naturally perceived, while at the same time realizing the maximum amount of detail and tonal range. The image is also corrected for white balance and neutrality by the use of light source recognition.

Image Expression Algorithms use the results from scene analysis to provide optimal adjustments to the face and other skin tone areas. Approximately 80% of consumer images consist of subjects containing people. Fujifilm has found that when a facial area can be recognized in an image, the correlation coefficient between the face density and target density is over 0.9, which means that the performance of the density correction becomes significantly better once the facial area can be recognized. The facial information can also be used for color correction and tone adjustments.

Many additional components are used in the new Image Intelligence software, which will provide customizable preference settings for the user. Some of the components that make up these critical analyses areas are described in Table 1.

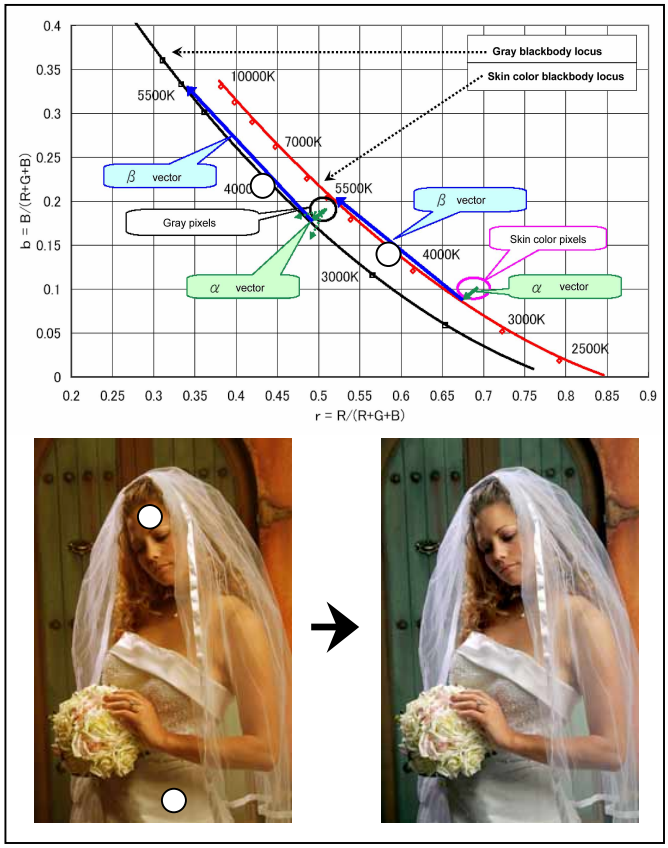
Table 1 : Sample of new Fujifilm Image Intelligence Features

Color Correction	Correction is optimized using facial extraction information and scene identification. Scene consistency from image to image has also been improved.
Density Correction	Overall density correction performance has been improved by the use of facial extraction information.
Contrast	Contrast performance has been improved for overexposed images, and skin tone contrast is lessened for smoother and more natural appearance.
Hypertone	Dynamic Range Control is used to optimize tonality and image detail, and skin tone areas are separated from other areas. Compression options are given to the user for more control and setting of preferences.
Hyper Sharpness	These algorithms help to improve the edge sharpness of the image while also helping to eliminate colored grains that tend to soften an image.
Gradation Adjust	Designed to give the best possible improvement in the highlights and shadows.
Full Auto Red Eye Correction	Automatically detects if there is red eye flash effect in the eyes of a face, and eliminates it.
USM	Use and strength adjustment of Un-Sharp Masking is available, and has been improved.
Bright Mode	The color saturation of primary colors can be increased or decreased without affecting the saturation of neutral colors or skin tones.
Noise Reduction	Dramatically helps to reduce image file noise and smoothes skin tone.

For photofinishing applications, these key components are integrated into Fujifilm's image server software, and will be customizable to provide optimal correction for a particular application. For the professional version of the software, many custom channels can be set up that can then be chosen in the workflow, and can also be used in conjunction with ICC compliant functions such as soft proofing and output rendering. The most effective advancements in the new Fujifilm Image Intelligence include automatic color balance techniques based on determining the original light source, color representation design, facial detection in the image, selective color saturation without affecting skin tones, and sharpening improvements.

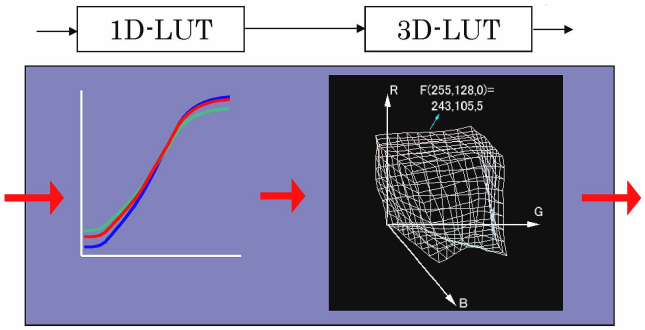
The technique of color correction for digital camera images is best performed by presuming the color temperature of the images, rather than doing light source recognition directly. In the new Fujifilm Image Intelligence, this is accomplished by detecting the gray pixel element and skin color element separately. There are several assumptions applied, including the fact that the light source is uniform, and that the color of the light source is located near the blackbody locus. The best determination of a scene's color temperature can be determined by extracting the minimal values of the absolute color temperature differences of gray and skin color. Linear programming methods can then be used to calculate the vectors for corrections. Color adaptation correction must also be recognized; this is the result of human color perception changing when the spectrum distribution changes. This calculation, shown in Fig. 1 as vector β, determines the amount of correction for the light source.

Fig. 1 *Color Temperature Adjustment for Digital Images*



Color representation for digital images is a two-stage process. Gray color representation is determined by the use of a 1D-LUT (Look Up Table). Here the tone curves of the original digital image, the design of the printer tone and the tone preference in the digital file are taken into account. Image processing for color representation is performed by the use of a 3D-LUT. Along with the image processing, preferences for optimum color reproduction are also considered. These include the color representation for blue sky, decreasing the failure for highly saturated cyan / green, and luminosity of reds. Additionally, skin color preference is accounted for by using a preferred hue angle adjustment.

Fig. 2 *Color Representation Design for Digital Images*



Facial detection technology used in the new Fujifilm Image Intelligence uses specific criterion for making the judgments. Once these determinations are made, the information can be used as part of the scene identification process, where factors such as direction, size and position of the face, light source, exposure, and background can be considered. The sophisticated algorithms also determine if it is a front-lit flash, back-lit, or normal scene type. Further analysis also considers correction stability in order to provide a consistent correction for similar images. Automatic correction of red-eye can also be provided as part of the process. Numerous facial features can be analyzed, including location of eyes and mouth to identify the person. It has been demonstrated that this technology can be used for other purposes, such as identifying faces in photo album software, allowing photos to be searched and sorted utilizing this data.

Fig. 3 *Face Recognition Process*

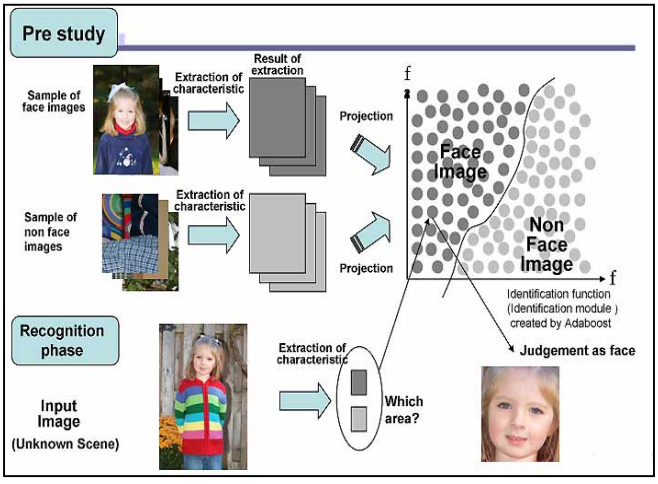
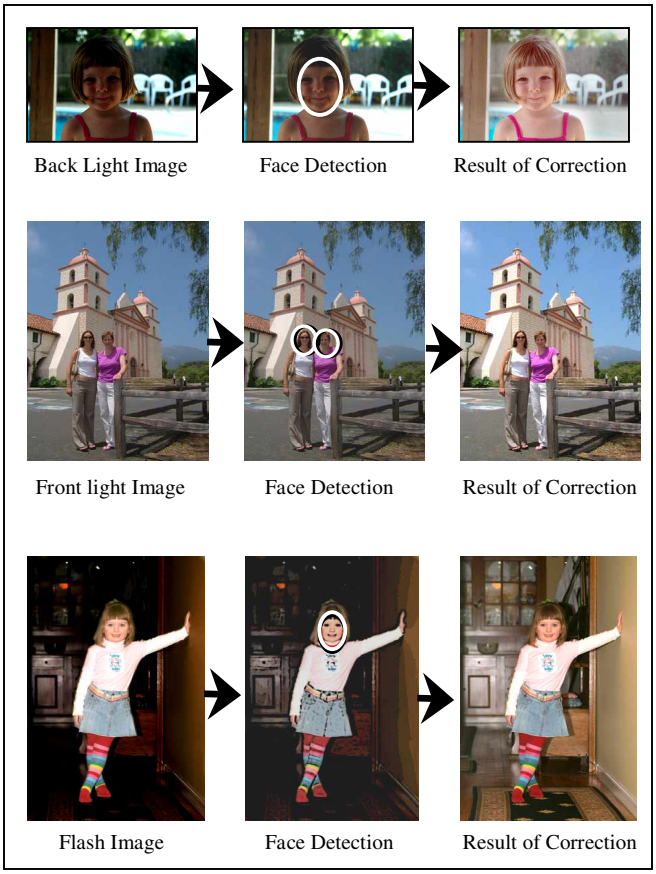
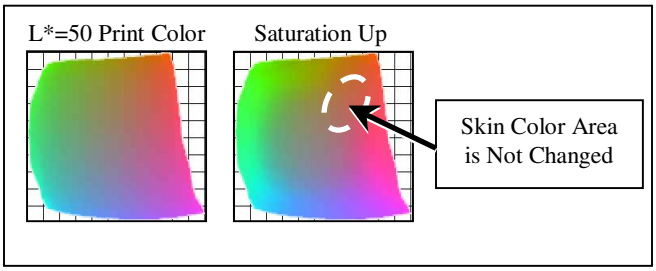


Fig. 4 *Effectiveness of Face Detection for Density*



Bright Mode is another feature of the new Fujifilm Image Intelligence that, when used in conjunction with all of the other parameters, will provide optimal image processing. It allows the color saturation of primary colors to be increased or decreased without affecting the saturation of neutral colors or skin tones. This is very effective in portraiture, where skin tone can become easily over-saturated when adjusting other colors in the image. Bright mode is executed by the adjustment of the parameter in the 3D-LUT.

Fig. 5 *Bright Mode Effect*



Conclusion

The goal of image processing is to reproduce an image exactly as it was seen and intended. Advancements in Fujifilm's new Image Intelligence technology provide the basis for this goal, which is to emulate as closely as possible the processes of the human brain. Fujifilm engages in activities with academic and research institutions in order to obtain expertise in these technologies. With Fujifilm's various companies and divisions working toward similar goals, including Fuji Photo Film, USA, Fuji Photo Film, Japan, Fujifilm Software-California, Fujifilm Graphics, Enovation, and others, Optimal Image Processing technology has become adaptive to many applications. Some of these applications have already been developed for use in the medical imaging field, and are used in Fujifilm's medical equipment such as Fuji Computed Radiography (FCR). Here Image Intelligence features such as gamma correction, Dynamic Range Control, energy subtraction, Pattern Enhancement for Mammography, and others are used. Graphics arts uses are also being developed for applications in pre-press proofing applications and stand-alone image processing software. Enovation's C-Fit software uses Image Intelligence Color-fitting Technology to achieve consistent image reproductions in all media.

Other new components being developed include auto-indexing with facial recognition, facial skin smoothing, anti-shake function, and auto portraiture for ID systems. The upcoming release of New Fujifilm Image Intelligence for Fujifilm's photofinishing systems will allow an advanced color correction system for consumer's digital images, and also provide an even more enhanced customizable feature set for professionals.

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