HP's Real Life Technologies for Image Enhancement

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Abstract

This presentation will focus on the key technologies HP uses to enhance images and how a central team of color, imaging, and software engineers created an imaging pipeline that has been ported across consumer, commercial and retail photo printing products.

Many real world examples are cited along with specific discussion of algorithms such as "Pet Eye" (red eye correction for animals). Some insights into our upstream techniques for image classification and analysis are discussed.

Ideas for future areas of research and development are also suggested.

History of HP's Real Life Technologies

Over the last dozen years, HP's digital imaging community has developed a suite of image enhancements marketed as "Real Life Technologies ™" (RLTs). Through careful design and robust software engineering, these technologies have been successfully leveraged across a wide range of products and services from our smallest snapshot printers to our Indigo production presses.

The RLT name was first marketed for HP Cameras and quickly spread to consumer printers, scanners and software. An excellent overview of the RLT suite used in HP products can be found on our company web site by searching on "Real Life Technologies."

While the RLT suite refers to a central collection of imaging algorithms, the actual pipelines produced for various product platforms were often customized. Image Enhancement (IE) algorithms in a camera, for example, are constrained to execute in an embedded environment, though much more information about the captured image is available compared to a software driver processing a random *jpeg* file one swath at a time.

In the section that follows, the evolution of the RLT print pipeline will be discussed. For the sake of clarity, a correction is anything that fixes a defect and an enhancement is something that makes an image more perceptually pleasing.

Overview of Specific Algorithms

The RLT print pipeline started in HP's DeskJet software drivers and evolved over the years. Variations on this pipeline are now active in everything from the firmware in our memory card slotted "walk up and print" or "direct connect" printers to our commercial retail photo center installations.

One of the first RLT's commercially delivered was the Smart Focus scaling algorithm that has been shipping since 1997. Smart Focus addressed the problem of printing low resolution imagery. Simply stated; customers were cutting, pasting, enlarging and printing low res clip art and images that looked fine on their monitors but bad when upscaled for printing resolutions. Simple schemes such as pixel replication often produced blocky or stair-step type artifacts. More sophisticated bi-cubic interpolation algorithms work by averaging neighboring pixels and produced smoother results, but tended to blur details.

Figure 1. *Smart Focus applied to web graphics*

Smart Focus is a form of Resolution Synthesis that was developed in collaboration with researchers at Purdue University. It was initially developed using a sophisticated training algorithm that examined large databases of high and low resolution image pairs. [1,2]

Smart Focus is powerful technology for enlarging images. It works by analyzing a local area and synthesizing new detail at the desired (higher) print resolution. The algorithm has evolved over time and continues to prove useful for applications ranging from printing simple web content to large format posters made from point-and-shoot digital camera.

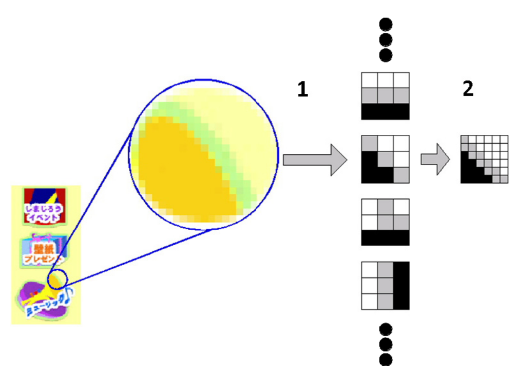

Figure 2. *Smart Focus uses filters to synthesize detail*

After scaling, the next set of technologies developed involved sharpness. Sharpening algorithms are present in most IE pipelines, however if not tuned properly they can do more harm than good.

HP's Spatial Fixed Resolution Enhancement "SFRE" sharpening is unique in that it optimizes the strength of the filter based on the input image size and print resolution. It also has extra logic built in to control changes in individual pixels so that they do not result in overshoot or undershoot. This avoids the common 'halo' effect seen with traditional approaches.

Another important aspect of perceived image quality is tone and contrast. HP has invented a number of algorithms that optimize contrast, while also enhancing detail typically lost in shadows [3,4]. These algorithms are collectively referred to as *Adaptive Lighting.*

Adaptive Lighting carefully balances overall tonal concerns within an image, and local shadow considerations. The end result is an improvement of overall tone and contrast, while at the same time revealing shadow detail that would otherwise be occluded.

Figure 3. *An otherwise "lost" photo is saved with RLT's*

Over time, the notion of Adaptive Lighting or "digital flash" evolved to include a number of technologies used to:

- Increase lighting in shadow regions of images.
- Bring dark subjects out of the shadows.
- Lighten dark (underexposed) images.
- Improves overall contrast.
- Adds saturation to some color regions

One of the novelties of our approach is the image *analysis* step that takes place before we do any enhancements. The RLT pipeline uses image understanding techniques to classify images in a way that allows us to optimize the parameters for the constituent algorithms. For instance, at a high level we attempt to determine many factors such as:

- Is it a night scene vs. day scene?
- Exposure: Under or over exposed?
- Is image backlit?
- Are faces and/or flesh tones present?
- Is noise present? If so, what kind?

Based on the classification results, parameters for adaptive lighting and global contrast enhancement settings are established. One of the benefits of this pre-analysis is that images that *don't* need fixing or enhancing are left untouched.

Human and Pet Eyes

Customer feedback continues to show that the most important IE we can offer is an accurate and automatic fix for flash-induced Red Eye. Scientists at HP Labs and our printer and camera divisions collaborated on a Red Eye algorithm that has shipped in many products and platforms. The most recent version includes a face detection stage to increase accuracy.

HP's automatic Red Eye uses a training based approach to discover and then correct flash induced red eyes. Variations of our red eye algorithms are used in most of HP's imaging products including: Cameras, Printers, Print Drivers, Photo Smart Express software, and Retail Photo Finishing stations.

We have benchmarked our algorithm against others in the industry and have consistently done well. No red eye algorithm is perfect, however. We have struggled with missing obvious cases and false-positives such as the red Christmas-tree light that get "corrected". Is it a failure or success when one eye is left red while the other is fixed? Imposing a heuristic to, say only correct pairs of eyes, has the effect of not correcting singletons that need correction. If the eye is corrected but the hue of the iris is wrong, would customers consider this a reasonable trade off? All these questions lead to optimization choices that could be improved.

We found through online experiments like *www.redbot.net,* that customers expected our Red Eye algorithm to work on their pets. It often did not since corresponding Pet Eye glow can be many other colors than red. This lead us to separately develop a Pet Eye Correction algorithm that removes the bright glare in animal eyes produces by flash photography. This heuristic based algorithm takes into consideration the various different colors that occur in Pet Eye, and the wide range of colors in surrounding animal fur. Pet Eye (unlike our red eye algorithm) also recreates glint when it re-colors the eye for a more natural effect. [5]

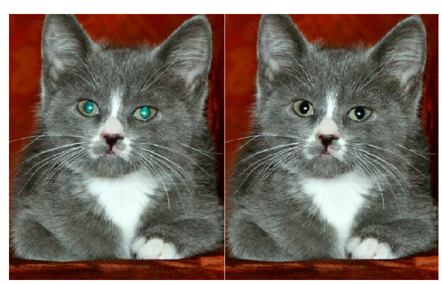

Figure 4. *Sasha the Cat before and after Pet Eye fix*

This algorithm originally shipped in 2007 with HP's R-series Cameras and won many rave reviews. It was next ported to a snapshot printer product line in 2008 (HP Photosmart A630). The algorithms were "semi-automatic" because both products had a

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touch screen interface that the customer uses to identify the eye in question. Roughly speaking, we find that about 80% of pet eyes were fixed with less than a 1% false positive rate.

We've yet to see an automatic human or pet eye correction that's perfect. The automatic pet eye version we posted to *www.snapfishlab.com* runs about 60% accurate with a 10% false positive rate. More research is needed to increase the accuracy when the customer is not in the loop.

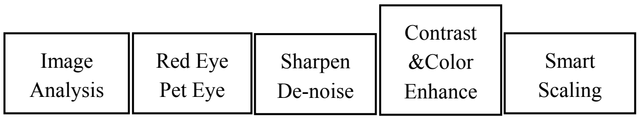

Figure 5. *Order of operations in RLT pipeline*

RLT Pipeline Leverage, Reuse, Evolution

While various RLT combinations and user interface configurations continue to ship in color Ink Jet and Laser Jet software drivers, the main recent activity has been adapting the pipeline to embedded, online, and high performance retail environments.

When we adapted our software pipeline to the embedded firmware environment, we encountered many hurdles to provide a pleasing, real-time interaction between a customer, a memory card, and a small printer. Challenges encountered included: code size, limited memory, converting floating point operations to integer math, and providing a preview that resembles the final printed output. Given the increasing quality of consumer photographs, Resolution Synthesis, for example, was deemed unnecessary in this environment. Red Eye, on the other hand, was essential.

We are pleased that our pipeline has scaled from the very tiny snapshot printers to the highest performance devices HP offers. Imaging researchers at HP Labs, Israel worked with our high speed Indigo press business to create the HP Indigo Photo Enhancement Server (HIPES). This technology was targeted at the high volume photo print service and finishing industry and runs on its own server. The original version of HIPES was heavily based on the RLT pipeline created for the consumer business.

When HP brought Ink Jet technology into the retail photo industry, the RLT pipeline was adapted for this high performance environment. We learned that in this environment, run time performance was just as critical as image quality. More importantly, the retail photo administrators requested features to be able to tune the system that represented a departure from our original target customer for, say, a PhotoSmart printer.

Color Preferencing for Retail Photo

In retail photography, our customers have expressed a need for both "professional photo" color reproduction, and "consumer photo" color reproduction and everything in between. To deliver functionality that can be considered similar to the variety of analog films people once used, we've created a user-selectable continuum of color reproduction choices that span from consumer to professional.

This approach gives the retail administrator the ability to tune their system to regional, corporate, or other preferred color reproduction. Our system holds skin tones accurate and uses a simple slider between pro and consumer preference to allowing other aspects such as vividness to vary. We also make a number of fixed settings available for the retail administrator to chose from.

In Fig. 6, we compare the original image with the enhanced version by the proposed method (we used mid-color temperature and mid-high saturation setting from the color preference slider). The preferenced image shows much crisper and punchier colors than those in the original image with proper levels of contrast and saturation while maintaining good color balancing and tone reproduction for flesh tones.

Figure 6. *Photo Before and after preferred color reproduction*

Thoughts for the Future

As consumer DSLR cameras, camera phones, and online services become pervasive, the need to process, enhance, and correct images will continue to provide researchers and companies with new challenges.

Accurate, automatic red eye correction remains elusive, and a merged and unified approach to human and pet eye corrections is an interesting area for investigation.

Image classification, segmentation, and, ultimately, understanding is another area that is rich for investigation. Where today we apply enhancements and corrections on an individual basis, in the future we may use analysis techniques on large groups of images. An obvious use-case for meta-analysis of groups of images would be a collage or photo book consisting of family pictures taken in different lighting conditions, or a collection of family pictures taken with different cameras.

It is the authors' observation that the fierce competition in the consumer market causes camera vendors to lead the way with novel features. A quick glance across recently introduced point-and-shoot cameras indicates that enhancements, corrections, and analyses are being combined into higher level functionality. Simple red eye or face-detection has given way to smile and blink detection, glamour filters such as slimming or teeth whitening.

In theory, it should be faster to innovate and deploy new technologies in software than in hardware. For this reason, online services are expected to play a key role in future breakthroughs.

The field of image correction and enhancement will remain a fertile area for innovation and invention in the future.

References

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Author Biography

Ron has advanced degrees in engineering from UCLA and currently manages a high powered team of color scientists and software engineers who work on technologies integral to HP's imaging businesses.

Morgan has Masters Degree in Computer Science from the University of Oregon and has been working on HP imaging technologies for over a dozen years.

They work together on a team that supplies technology and tools for consumer printing and imaging across HP.

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