Ghostscript's ICC-based Color Architecture

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Outline

- Ghostscript Overview
- PDLs & Color Spaces
- Existing Ghostscript ICC Flow
- New Architecture

About Ghostscript

- Ghostscript is a document conversion and rendering engine.
- Essential component of the Linux printing pipeline.
- Dual GPL/Proprietary licensed. Artifex owns the copyright.
- Source and documentation available at www.ghostscript.com

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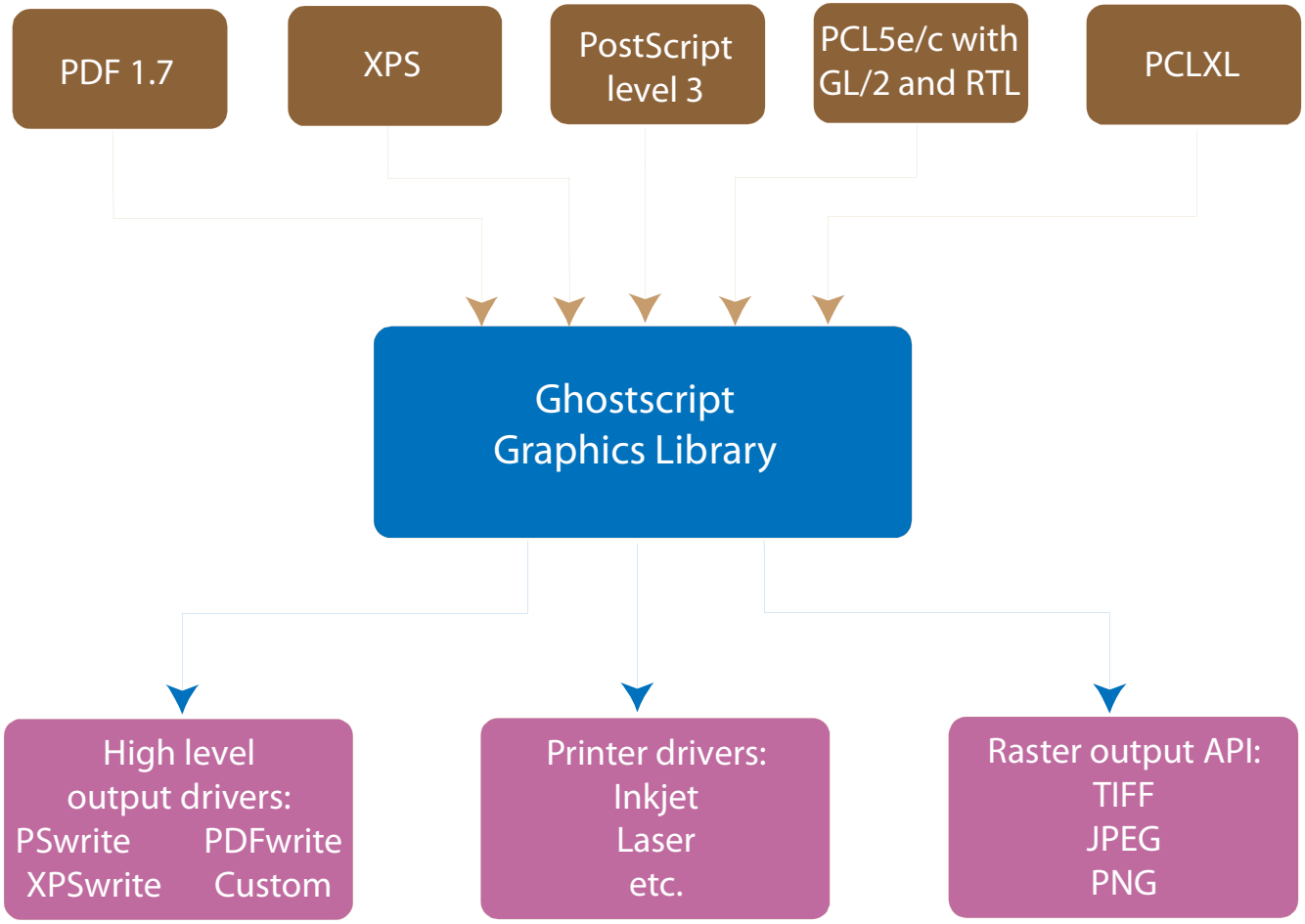
Ghostscript Overview



PDLs and Color Spaces: Overview

PostScript Level 3 – DeviceGray, DeviceRGB, DeviceCMYK, Device independent color spaces 1, 3,and 4 component (CIEXYZ based), Separation, N-Device, Indexed, and Pattern.

PDF – Essentially same as PSL3, but adds ICCBased as input type and loses some PS CIE based spaces. Adds a LAB type. Only supports 1, 3 or 4 channel ICC profiles.

PCL – RGB based. Color assumed to be sRGB.

XPS, OpenXPS, SVG – All color defined by ICC profiles. XPS allows up to 8 channels.

Ghostscript supports ALL.

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Current code base and ICC Color Spaces

Today, most print/display color management is handled completely through the use of ICC profiles.

Ghostscript supports all color spaces defined by PSL3 and PDF1.7 with the exception of support of V4 ICC profiles. Ghostscript supports ICC.1:1998-09 (vers 3.4).

The existing architecture is inefficient in its use of ICC profiles due to their late addition into the code. (Last color space added).

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Primary Color Flows in Ghostscript

A Color Rendering Dictionary (CRD) is PostScript's method for defining a mapping from CIEXYZ to a device color. It can be defined with PS procedures (functions) and/or multi-dimensional look-up-tables.

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Current ICC Usage in Ghostscript. No Linking!

For each image pixel……

RGB Image

Scanner M LUT
ICC Profile
PCS is CIELAB

Map to CIELAB via MLUT

CIELAB

Map to CIEXYZ via Function

CIEXYZ

Map to device space using CRD. Default is sRGB based

RGB

Map to device process color space

CMYK

Note: If CRD is also an MLUT, we end up going through two MLUTS!

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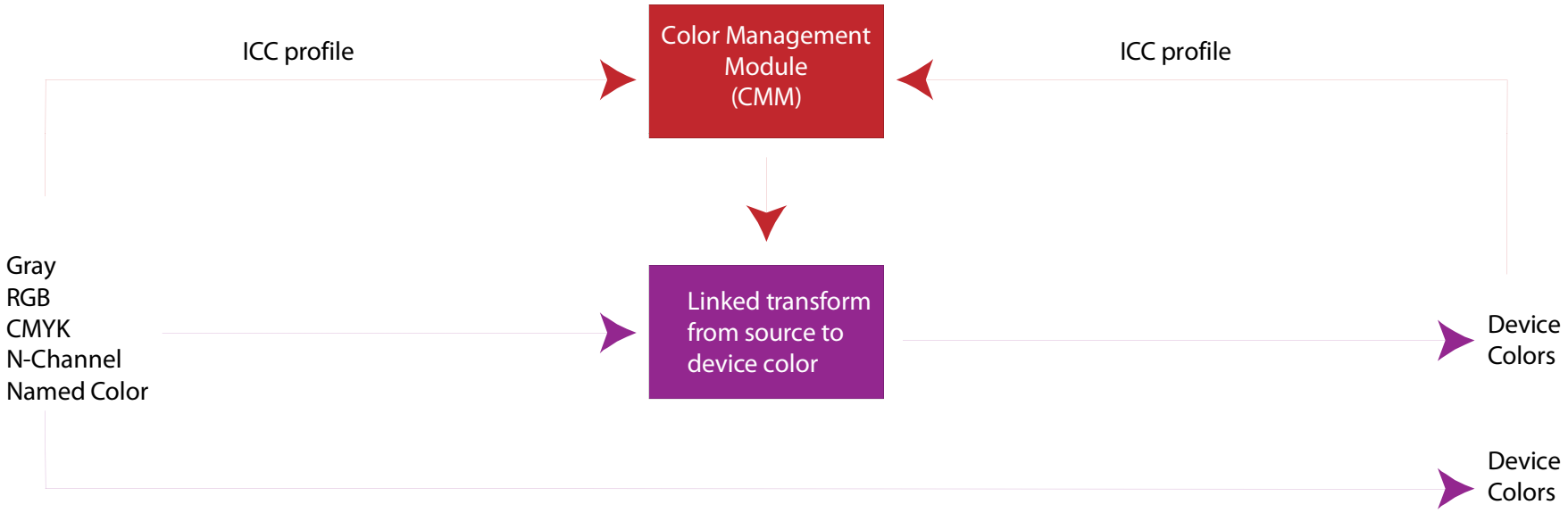
Desired Color Flows



Even if it is ICC centric, Ghostscript will continue to support the non-ICC color spaces of PDF and PostScript.

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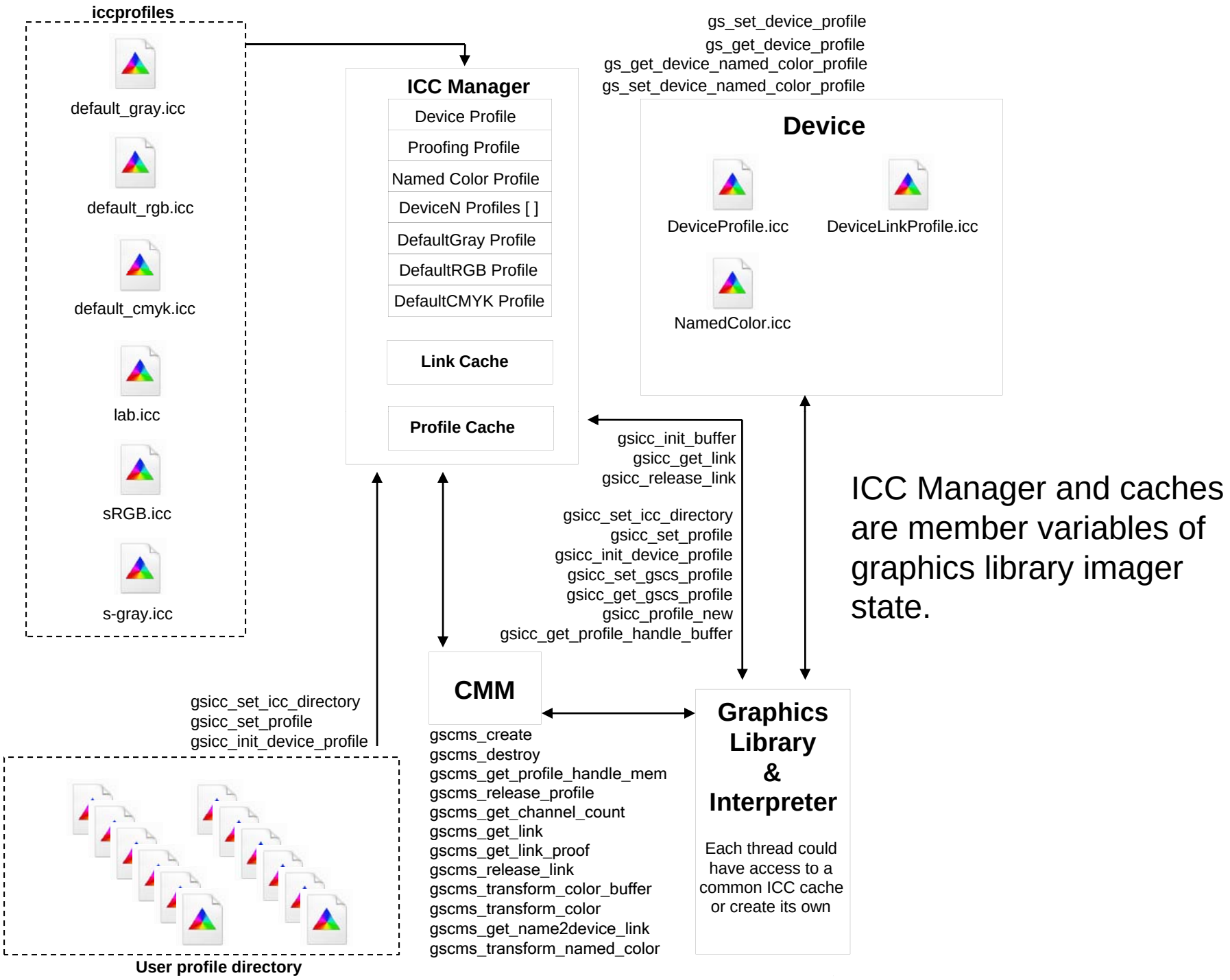
Goals of New Ghostscript Color Architecture

- Easy to interface different CMM with Ghostscript.
- Define ALL color spaces in terms of ICC profiles.
- Cache linked transformations and internally generated profiles.
- Easily accessed manager for ICC profiles.
- Devices communicate their ICC profiles and have their ICC profile set.
- Include object type (e.g. image, graphic, text) and rendering intent into the computation of the linked transform.
- Operate efficiently in a multithreaded environment.
- Handle named colors with ICC named color profile or proprietary format.
- Color management of Device-N colors.
- Flexibility for proofing, profile override, default settings and device link profiles.


iccprofiles
default_gray.icc
default_rgb.icc
default_cmyk.icc
lab.icc
sRGB.icc
s-gray.icc
ICC Manager
Device Profile
Proofing Profile
Named Color Profile
DeviceN Profiles [ ]
DefaultGray Profile
DefaultRGB Profile
DefaultCMYK Profile
Link Cache
Profile Cache
gs_set_device_profile
gs_get_device_profile
gs_get_device_named_color_profile
gs_set_device_named_color_profile
Device
DeviceProfile.icc
DeviceLinkProfile.icc
NamedColor.icc
gsicc_init_buffer
gsicc_get_link
gsicc_release_link
gsicc_set_icc_directory
gsicc_set_profile
gsicc_init_device_profile
gsicc_set_gscs_profile
gsicc_get_gscs_profile
gsicc_profile_new
gsicc_get_profile_handle_buffer
CMM
gsicc_set_icc_directory
gsicc_set_profile
gsicc_init_device_profile
gscms_create
gscms_destroy
gscms_get_profile_handle_mem
gscms_release_profile
gscms_get_channel_count
gscms_get_link
gscms_get_link_proof
gscms_release_link
gscms_transform_color_buffer
gscms_transform_color
gscms_get_name2device_link
gscms_transform_named_color
Graphics Library & Interpreter
Each thread could have access to a common ICC cache or create its own
User profile directory
ICC Manager and caches are member variables of graphics library imager state.

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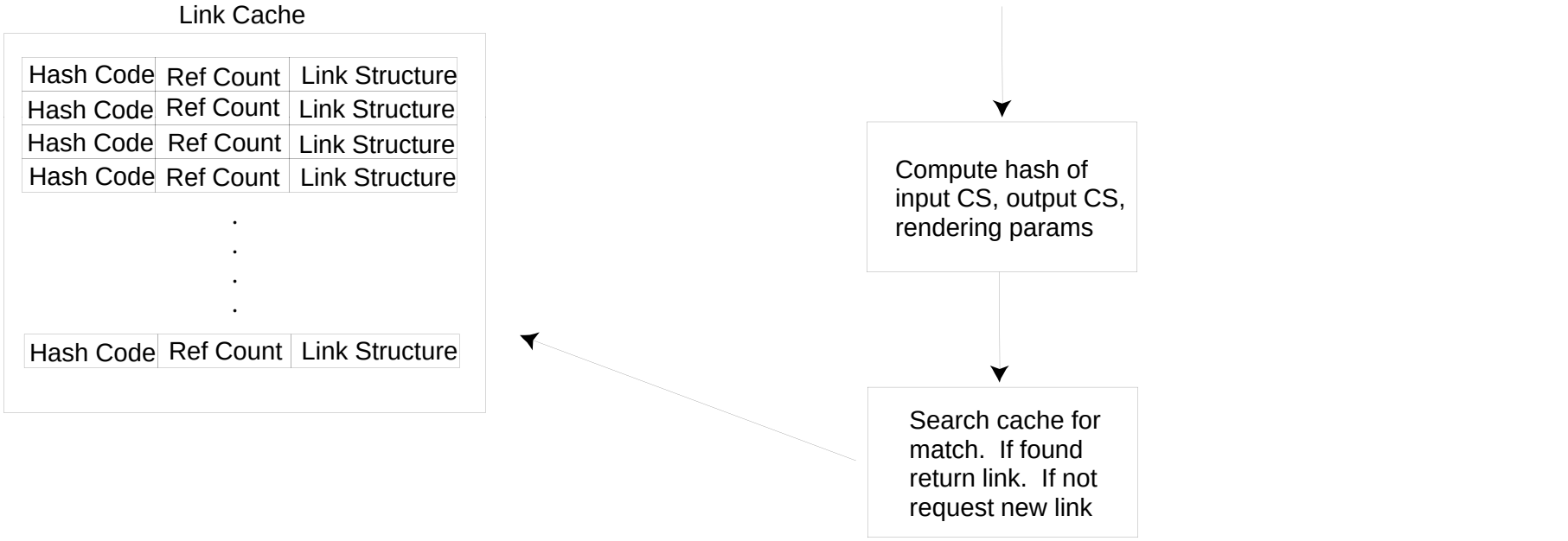
Typical Graphics Library Usage

- Graphics library will request link from link cache.
- Once link obtained, graphics library will apply link to buffers. Typical buffer may be a single scan line.
- When done, graphics library will notify cache.
- Ideal buffer transform case occurs in transparency code when transforming from blending color space during transparency group pop.

Link Cache

GRAPHICS LIBRARY

gsicc_get_link(* pis, *input_colorspace, *output_colorspace, *rendering_params, *memory, include_softproof)



Link entries are reference counted.

Links are only released if we are at maximum number (or memory), new request is made and a Ref Count is one.

Named Colors

	Required	Optional
Pantone Uncoated Yellow	CIELAB	Device Value
Toyo Red	CIELAB	Device Value
Pantone Coated Green	CIELAB	Device Value
.		
.		
.		
Toyo Coated Blue	CIELAB	Device Value

A look-up-table.

There is an ICC profile format for named colors.

In many applications, a custom format is used.

For some companies this is their value added.

Missing from ICC profile is ability to use tint information. We provide opportunity for CMM to use. If it cannot, then alternate tint transform is used.

```
int gscms_transform_named_color(gsicc_link_t *icclink,
                                float tint_value,
                            const char *ColorName,
                        gx_color_value device_values[]);
```

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Conversion of PS and PDF Color Spaces

- PS and PDF CIE color spaces are converted to ICC forms that the CMM can handle.
- PS mappings are all 1-way. Device to CIEXYZ or CIEXYZ to Device.
- Procedural mappings are sampled.
- Because of the multiple matrix operations and procedural mappings, some PS color spaces that do not include MLUTs will give rise to ICC profiles that do include MLUTs.

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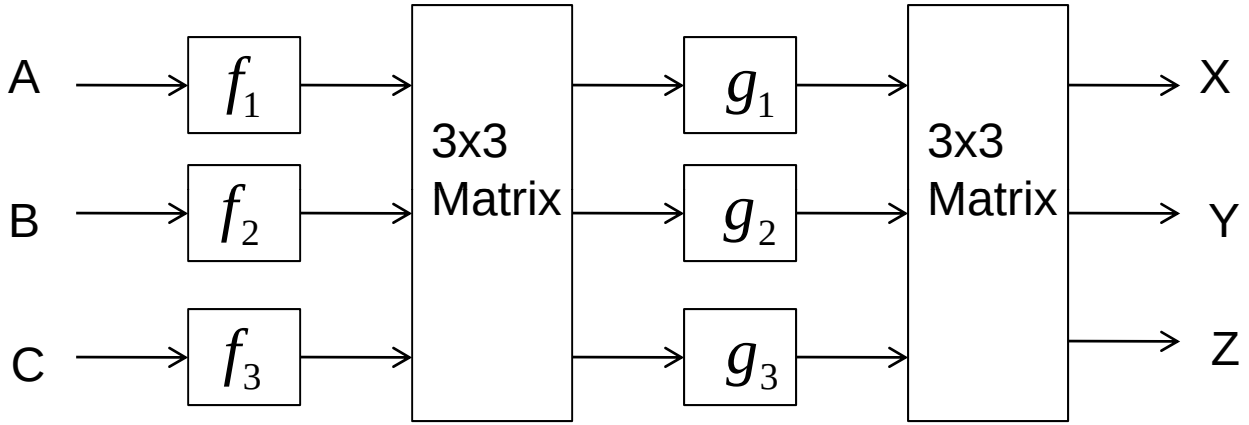
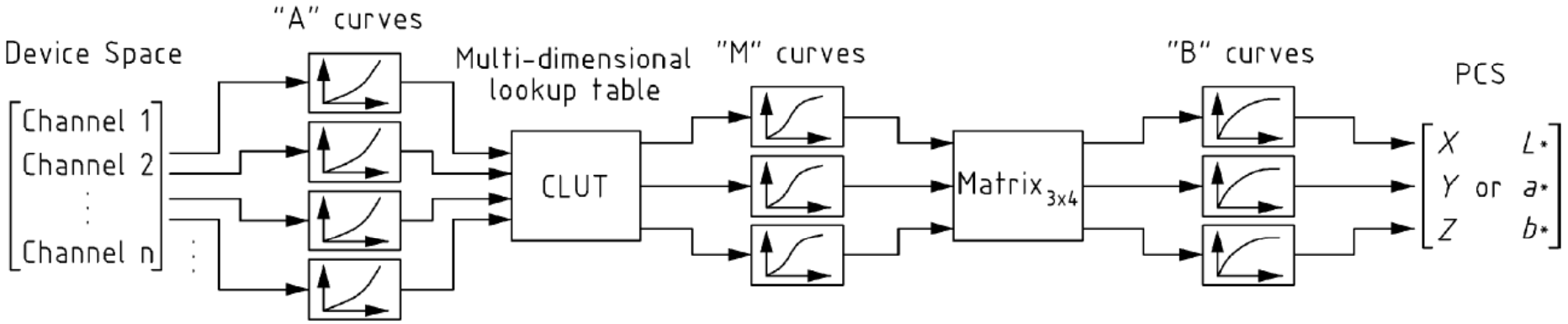
Example PS CIEABC





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Profile Cache

- Ghostscript creates ICC profiles from PDF and PS CIE colorspace definitions (e.g. CalRGB, CIEABC, CIEDEFG)
- To avoid repeated creations, these profiles are cached based upon a hash code that is related to the resource ID.
- Cache is designed such that MRU item is at the top of the list.
- Profiles are only released if we are at maximum number (or memory), new request is made and a reference count is one.

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Device N color spaces (PDF and PS)

For Device N output, very simple to provide capability for N -color ICC profile.

Many desire to have CM with CMYK and to pass additional spot colors unmolested.

For DeviceN input color, XPS requires ICC profile. PDF and PS use an alternate tint transform.

New architecture provides capability to define N-color ICC profile for DeviceN input colors to replace the alternate tint transform if desired.

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Ghostscript's Command List

- Ghostscript normally renders in immediate mode.
- Can also generate a command list for asynchronous processing.
- Subdividing a job into bands reduces peak memory usage.
- Threads can process bands simultaneously.

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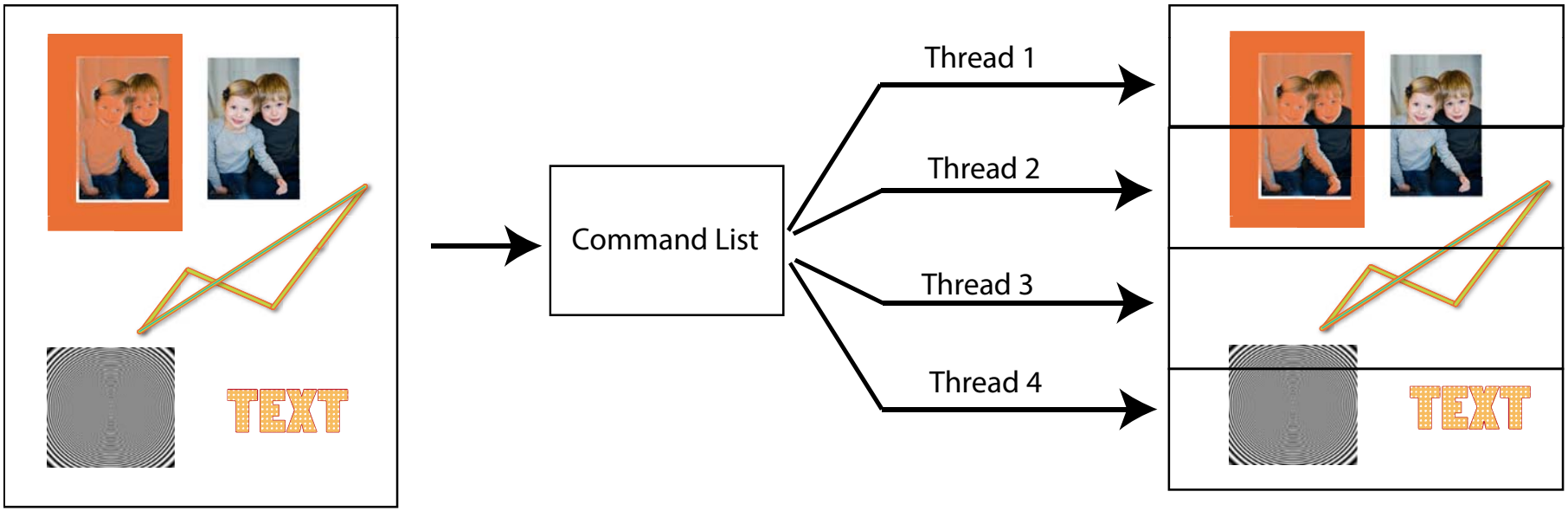
Ghostscript Multithreaded



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Command List and ICC Profiles

- Due to table look-ups and interpolations color conversion is expensive.
- Would like to distribute the load in threaded rendering.
- ICC profiles are embedded in the command list.

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Multi-Threaded Environment

- During command list read phase, each thread obtains the same initial imaging state that includes a pointer to the primary link cache.
- In a single page, it is very likely that similar links will be needed.
- This suggests sharing a common cache amongst the threads.
- Links are reference counted to ensure only unreferenced ones are removed.
- Necessary to have a lock and release feature on the cache.

CMM API

Get Profile Operations

```
gcmmhprofile_t gscms_get_profile_handle_mem(unsigned char *buffer,
                                            unsigned int input_size);

gcmmhprofile_t gscms_get_profile_handle_file(const char *filename);
```

CMM API

Get Link Operations

```
gcmmhlink_t gscms_get_link(gcmmhprofile_t lcms_srchandle,
                           gcmmhprofile_t lcms_deshandle,
                           gsicc_rendering_param_t *rendering_params);

gcmmhlink_t gscms_get_link_proof(gcmmhprofile_t lcms_srchandle,
                                 gcmmhprofile_t lcms_deshandle,
                                 gcmmhprofile_t lcms_proofhandle,
                                gsicc_rendering_param_t *rendering_params);

gcmmhlink_t gscms_get_name2device_link(gcmmhprofile_t  lcms_srchandle,
                                       gcmmhprofile_t lcms_deshandle,
                                       gcmmhprofile_t lcms_proofhandle,
                                 gsicc_rendering_param_t *rendering_params)
```

CMM API

Transform Color Operations

```
int gscms_transform_color(gsicc_link_t *icclink, void *inputcolor,
                          void *outputcolor, int wordwidth);


void gscms_transform_color_buffer(gsicc_link_t *icclink,
                                  gsicc_bufferdesc_t *input_buff_desc,
                                  gsicc_bufferdesc_t *output_buff_desc,
                                  void *inputbuffer, void *outputbuffer);

int gscms_transform_named_color(gsicc_link_t *icclink,
                                float tint_value,
                                const char* ColorName,
                                gx_color_value device_values[]);
```

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CMM API

Information Operations

```
int gscms_get_channel_count(gcmmhprofile_t profile);

gsicc_colorbuffer_t gscms_get_profile_data_space(gcmmhprofile_t profile);

int gscms_get_pcs_channel_count(gcmmhprofile_t profile);


char* gscms_get_clrtname(gcmmhprofile_t profile, int colorcount);

int gscms_get_numberclrtnames(gcmmhprofile_t profile);
```

CMM API

Overhead and Cleanup Operations

```
void gscms_create(void **contextptr);
void gscms_destroy(void **contextptr);
void gscms_release_link(gsicc_link_t *icclink);
void gscms_release_profile(gcmmhprofile_t *profile);
```

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Command Line Interface

Source Default Profiles

-sDefaultGrayProfile = my_gray_profile.icc
-sDefaultRGBProfile = my_rgb_profile.icc
-sDefaultCMYKProfile = my_cmyk_profile.icc
-sDeviceNProfile = my_devicen.icc

Device Profile

-sOutputICCProfile = my_device_profile.icc

ICC Search Directory

-sICCProfilesDir = c:/my_iccprofiles/

Other Settings

-sProofProfile = my_proof_profile.icc
-sNamedProfile = my_namedcolor_profile.icc
-sDeviceLinkProfile = my_link_profile.icc

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Performance

Image with ICC source profile RGB MLUT

Renders twice as fast with new architecture

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Performance

CIELAB Image

Renders three times as fast with new architecture

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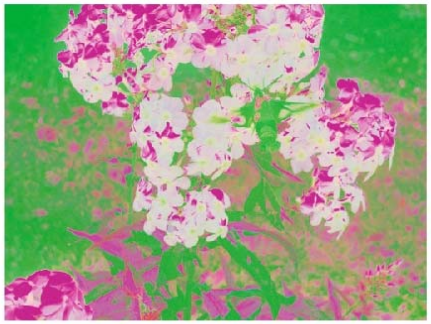
Performance

Rendering intent test with trunk

Perceptual Rendering Intent

Saturation Rendering Intent



Relative Colorimetric Rendering Intent

Absolute Colorimetric Rendering Intent

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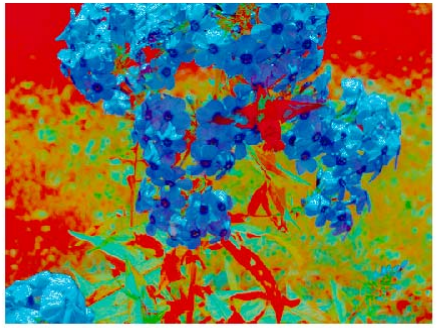
Performance

Rendering intent test with new architecture



Perceptual Rendering Intent

Saturation Rendering Intent

Relative Colorimetric Rendering Intent

Absolute Colorimetric Rendering Intent

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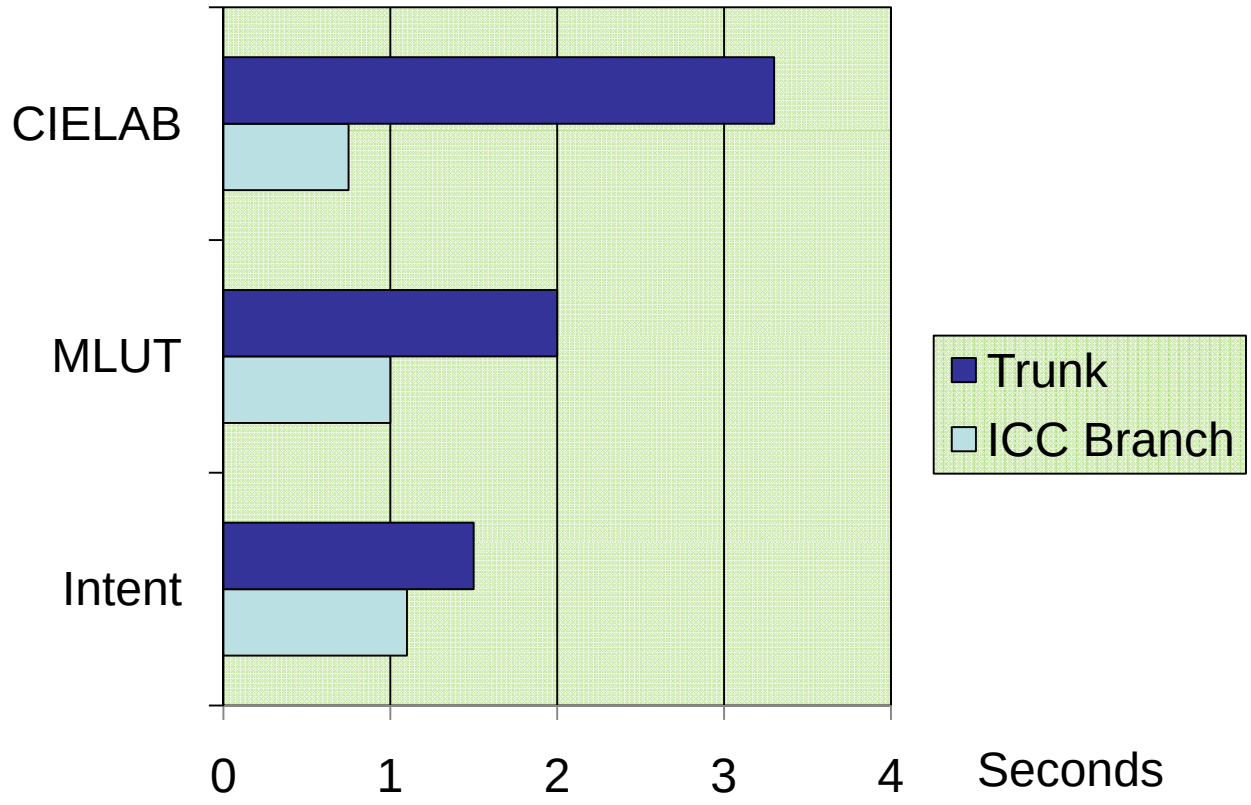
Performance



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Current Status

- ICC branch in SVN.
  http://svn.ghostscript.com/ghostscript/branches/icc_work
- Currently interfacing to littleCMS http://www.littlecms.com/ Marti Maria.
- Merge soon with trunk for August release.
- Reviewing regression differences.