Ghostscript's ICC Colour Architecture

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Outline

- Ghostscript Overview
- PDLs & Colour Spaces
- Problems in Existing Ghostscript ICC Flow
- New Architecture and API

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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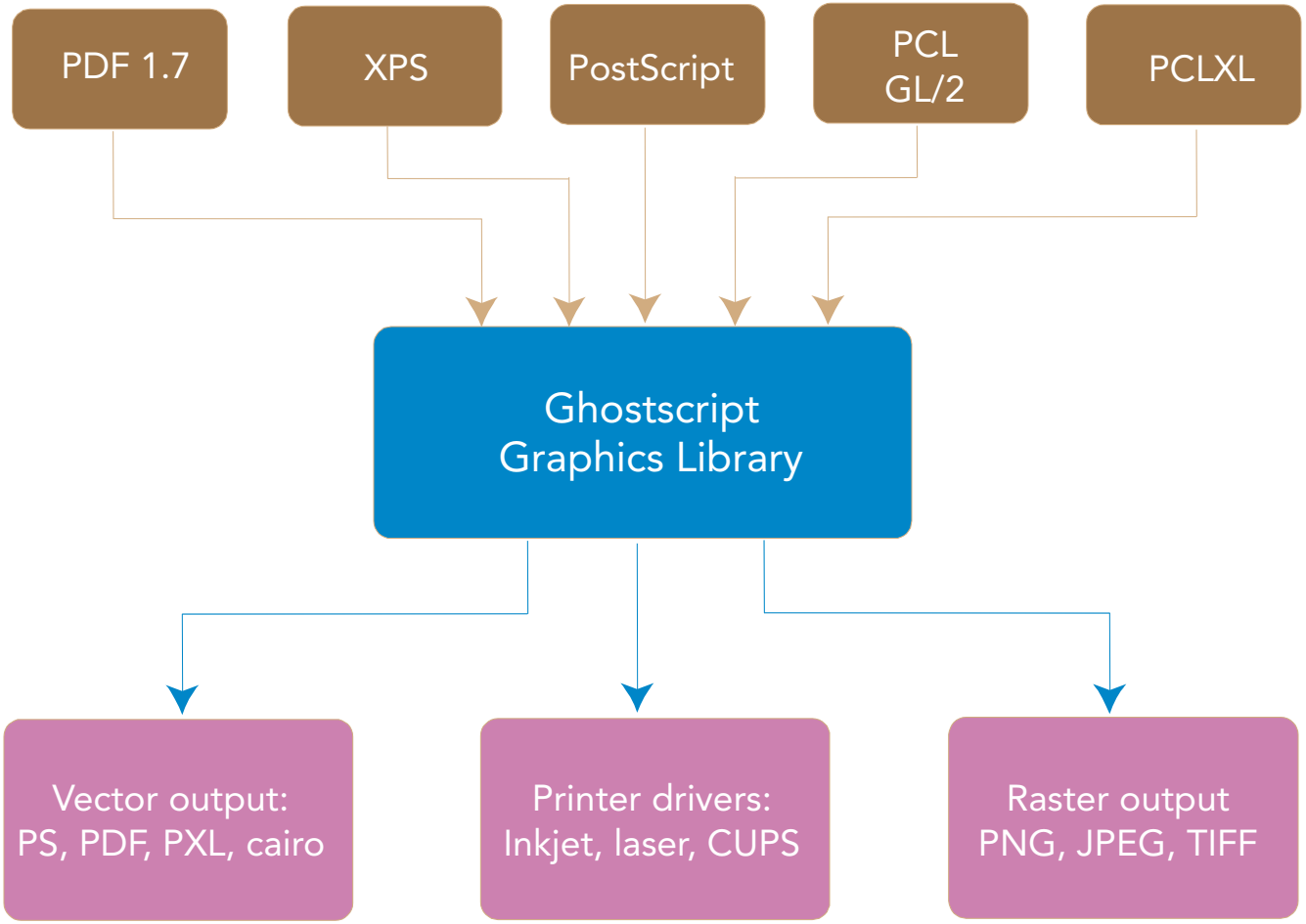
Ghostscript Overview



Our Place in the Stack

- Application generates page for print
  - Drawing through Cairo/GTK/Qt -> PDF
  - or generate PostScript directly
- Page descriptions are passed to CUPS
- CUPS manages queues for each printer
- Looks up per-queue configuration
- Passes file directly to smart printers
- Calls Ghostscript as a filter to flatten or rasterize for dumb printers

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Colour Spaces

- Different devices represent colour differently
- Screens, cameras: Red, Green, Blue
- Print: Cyan, Magenta, Yellow, Black
- Video: Luminance, Red and Blue Chroma

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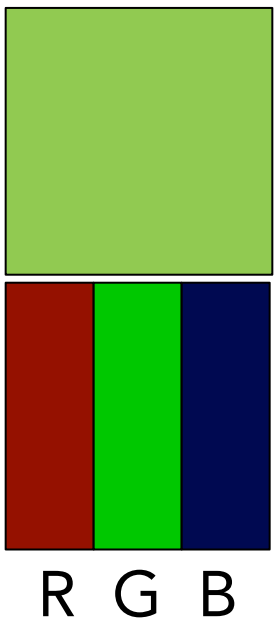
RGB



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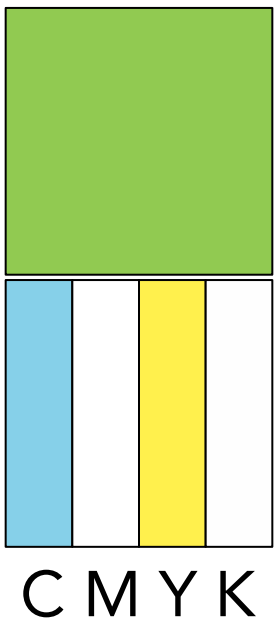
CMYK



Accurate Colour

Which Red, Green, and Blue?

ICC Profiles

PDLs and Colour Spaces: Overview

PostScript Level 3 – DeviceGray, DeviceRGB, DeviceCMYK, Device independent colour 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. Colour assumed to be sRGB.

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

Ghostscript supports ALL.

Ghostscript and ICC Colour Spaces

Today, colour management in prepress environments is handled completely through the use of ICC profiles.

Ghostscript supports all colour 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 colour space added).

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Primary Colour Flows in Ghostscript

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

Current ICC Usage in Ghostscript. No Linking!

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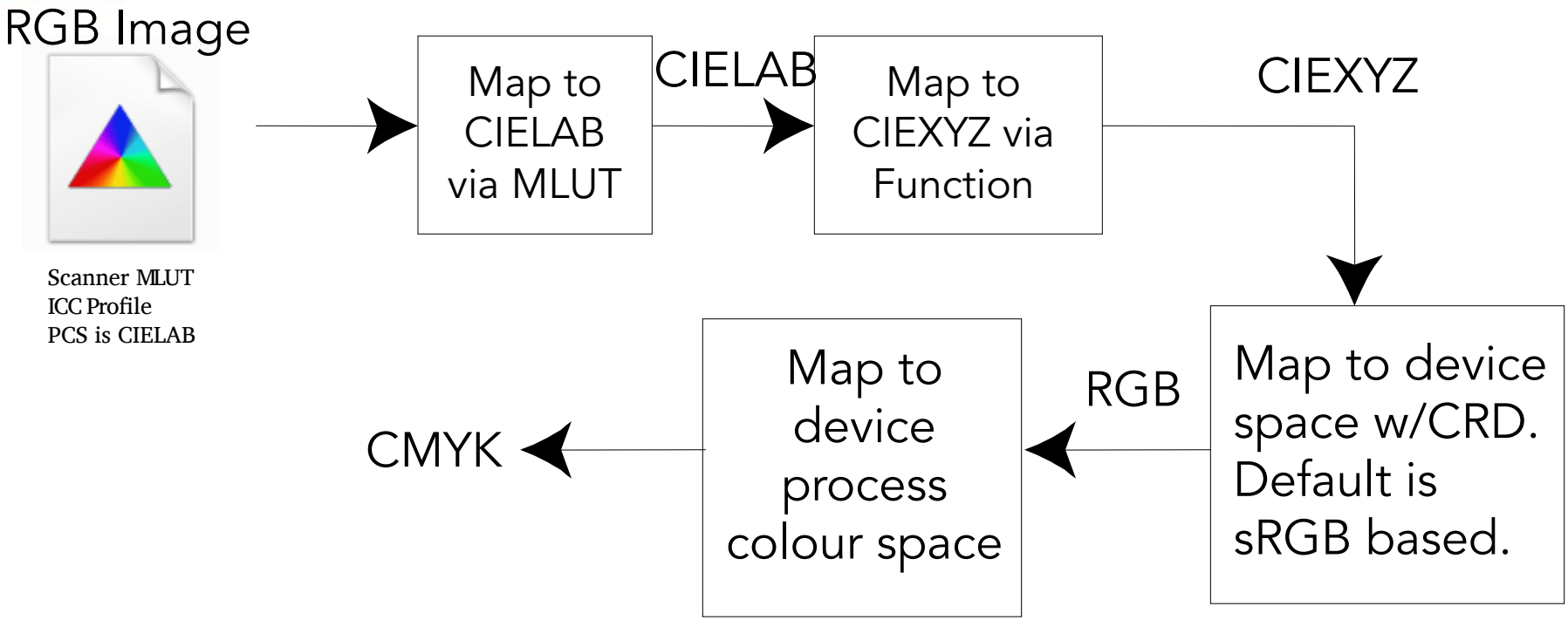
For each image pixel……



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

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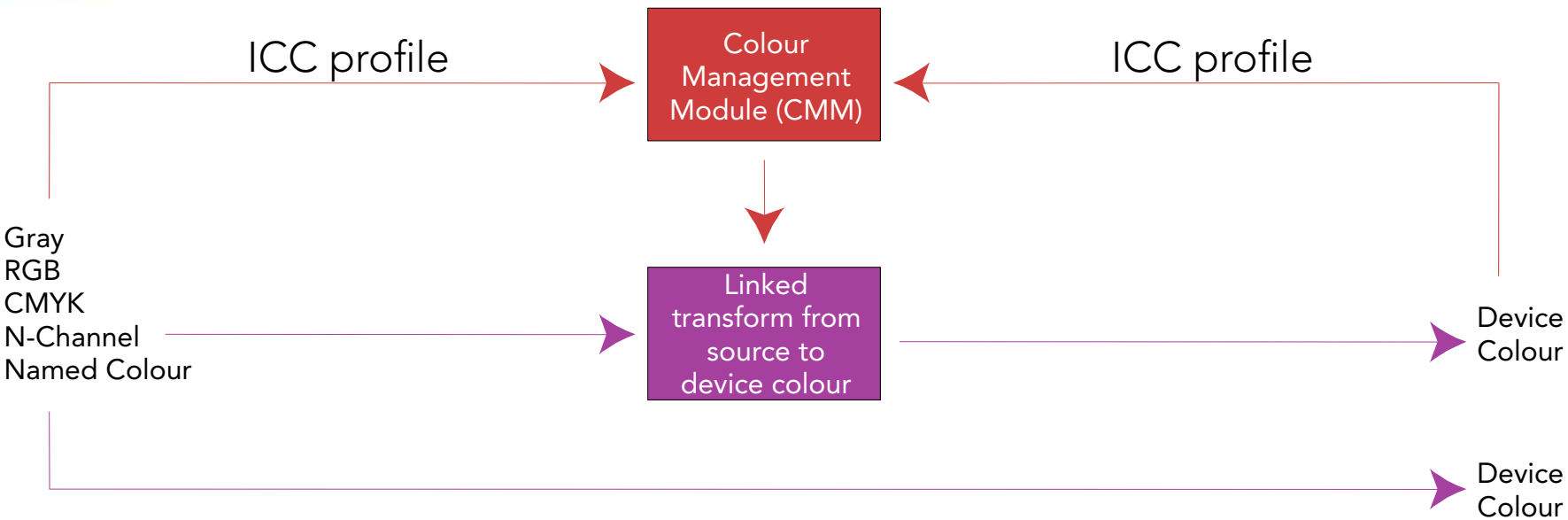
Desired Colour Flows



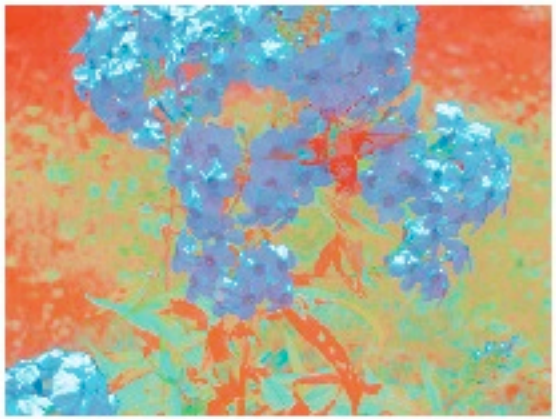
Even if it is ICC centric, Ghostscript will continue to support the colour spaces of PDF and PostScript.

MLUT Image

rendering through lcms is twice as fast

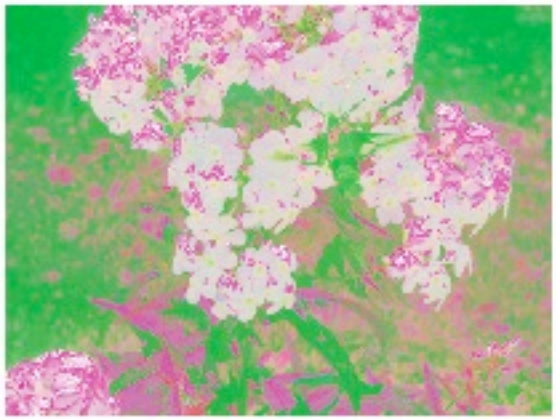

CIE Lab Image
rendering through lcms is *three times* as fast

ICC rendering intent test



Perceptual Rendering Intent

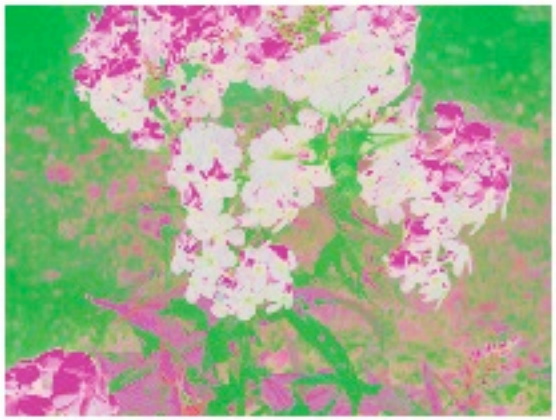
Saturation Rendering Intent



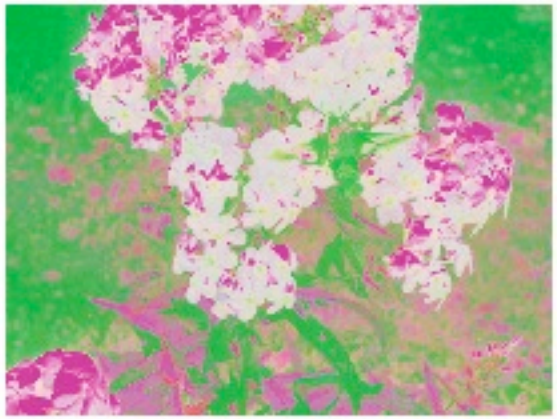
Relative Colorimetric Rendering Intent

Absolute Colorimetric Rendering Intent

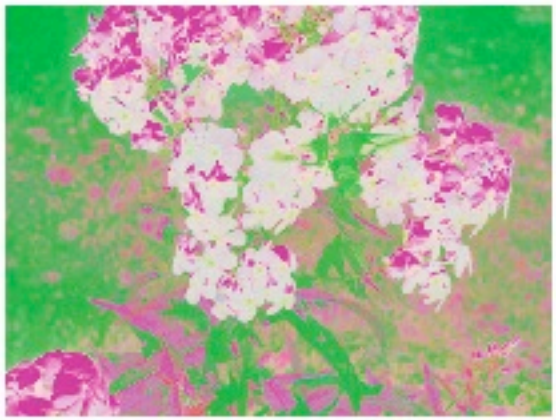
Ghostscript trunk



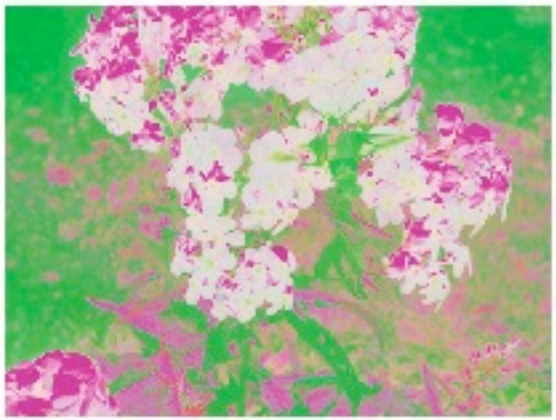
Perceptual Rendering Intent



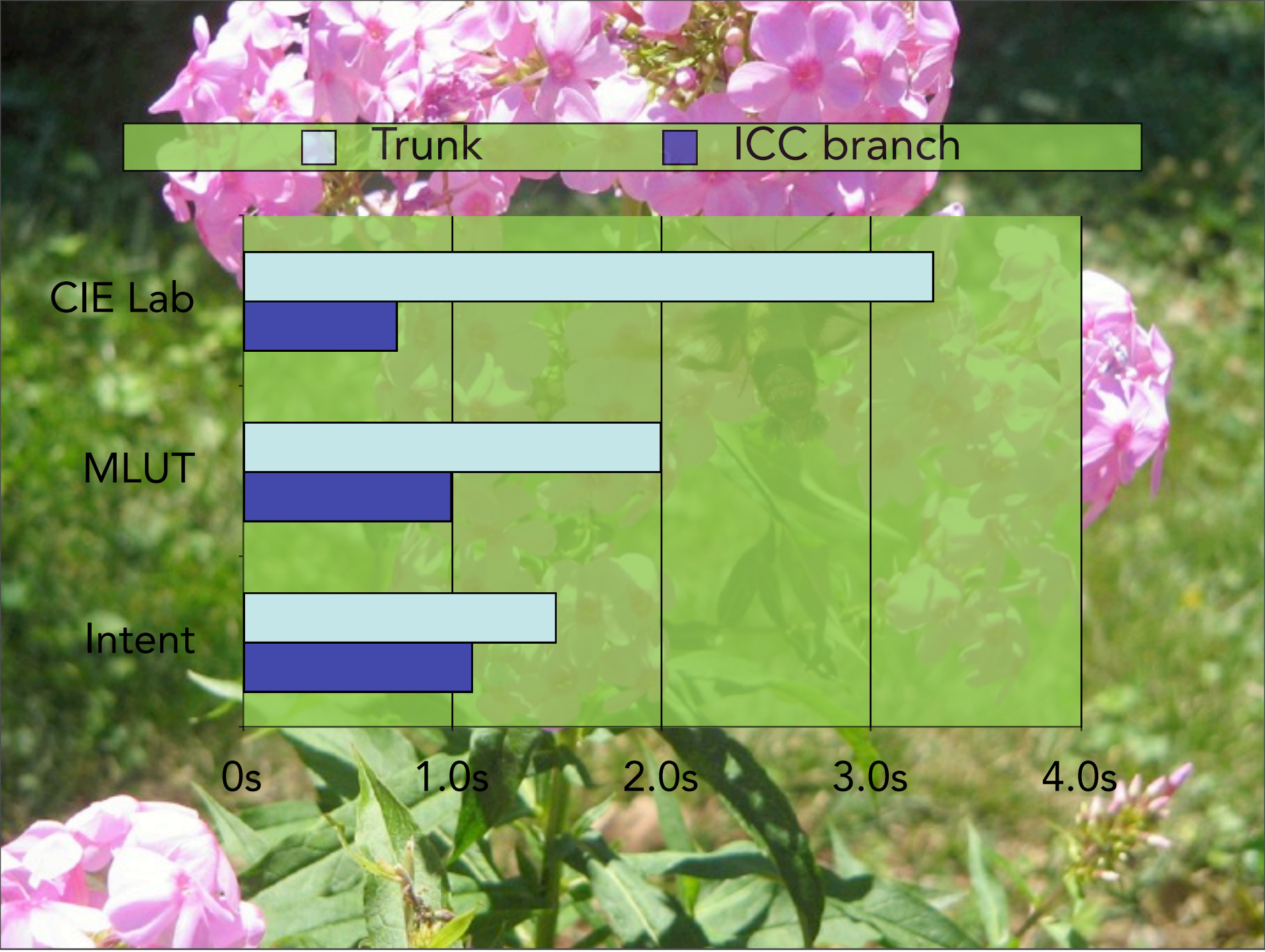
Saturation Rendering Intent



Relative Colorimetric Rendering Intent



Absolute Colorimetric Rendering Intent


Trunk
ICC branch
CIE Lab
MLUT
Intent
0s
1.0s
2.0s
3.0s
4.0s

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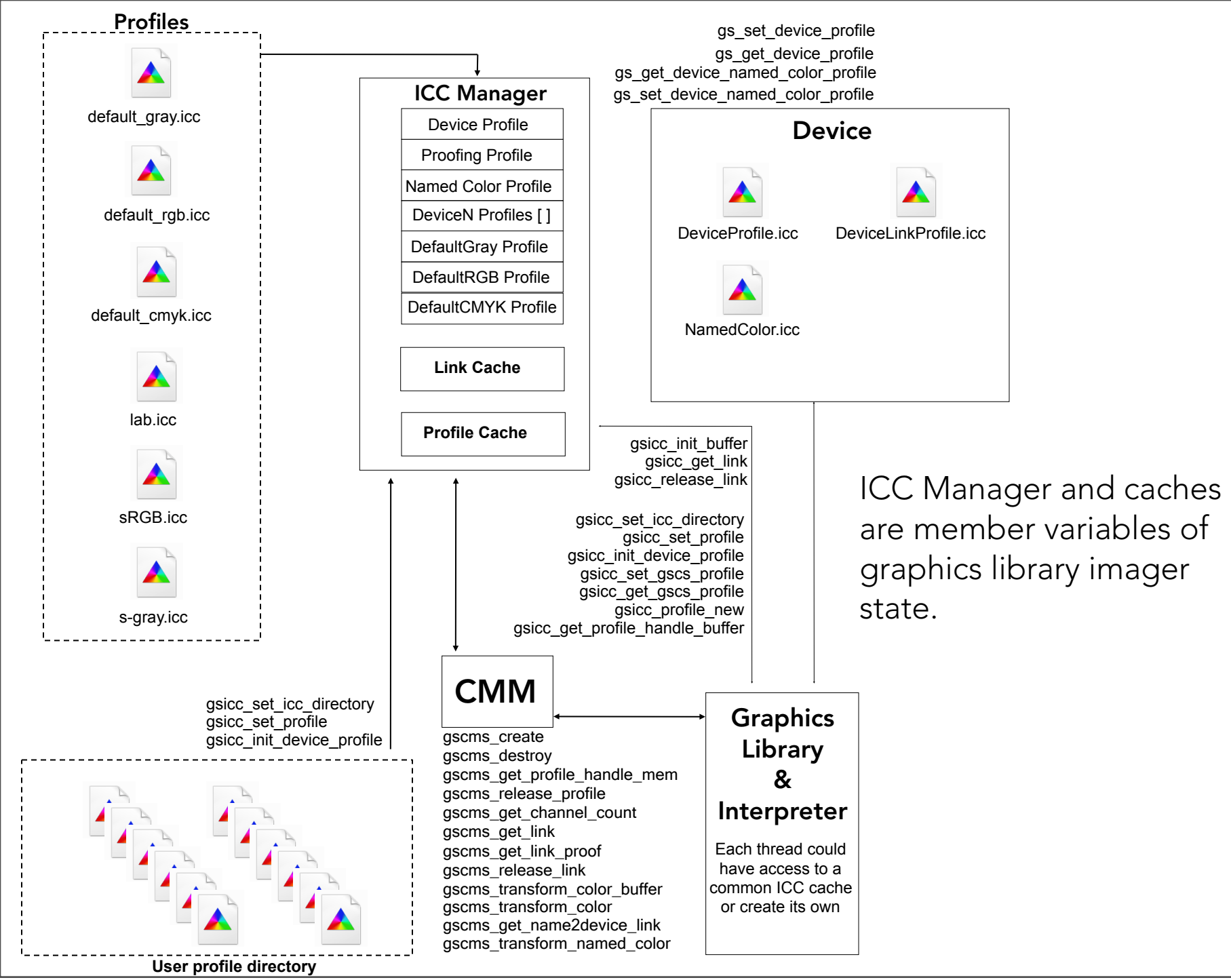
Goals of New Ghostscript Colour Architecture

- Easy to interface different CMM with Ghostscript.
- Define all colour spaces in terms of ICC profiles.
- Cache linked transformations and 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.
- Colour management of multichannel “DeviceN” colours.
- Handle named colours with ICC named colour profile or proprietary format.


Profiles
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.

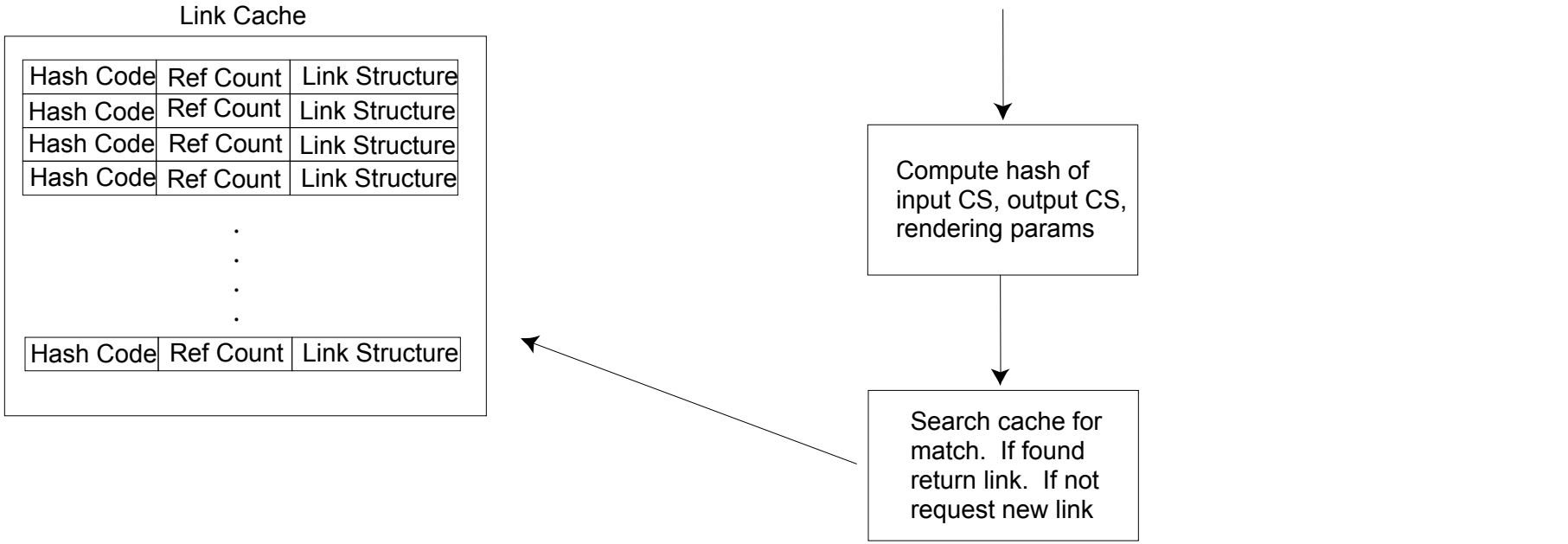
Typical Graphics Library Usage

- 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 colour 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 zero.

Named Colours

	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 colours.

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 CMS to use. If it cannot, then alternate tint transform is used.

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

Conversion of PS and PDF Colour Spaces

- PS and PDF CIE colour spaces will be converted to ICC forms that the CMM can handle.
- If desired CMM could be provided with PS or PDF data in a private tag.
- PS mappings are all 1-way. Device to CIEXYZ or CIEXYZ to Device.
- Procedural mappings will be sampled. This is already done in Ghostscript's joint CIE cache for transforming CIE based colours.
- Because of the multiple matrix operations and procedural mappings, some PS colour spaces that do not include MLUTs will give rise to ICC profiles that do include MLUTs.

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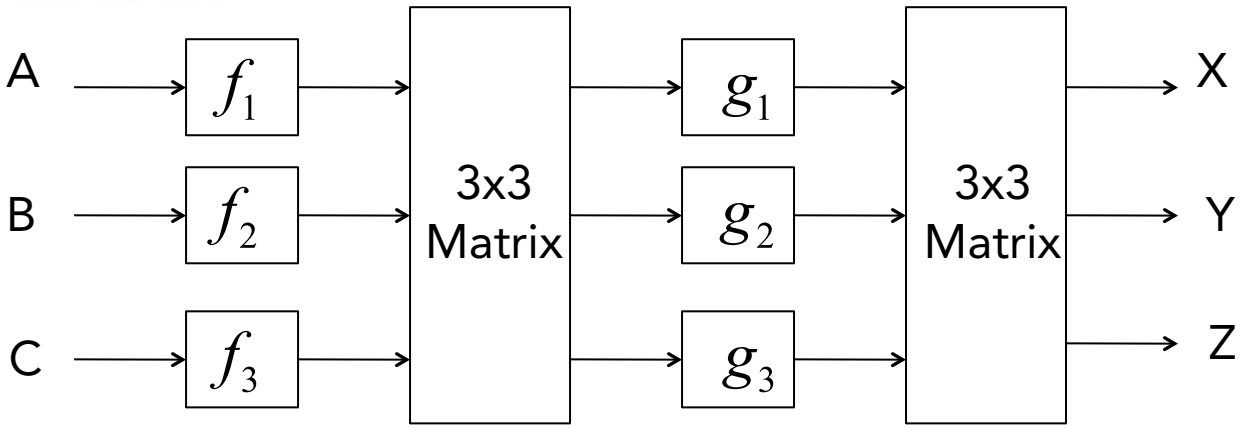
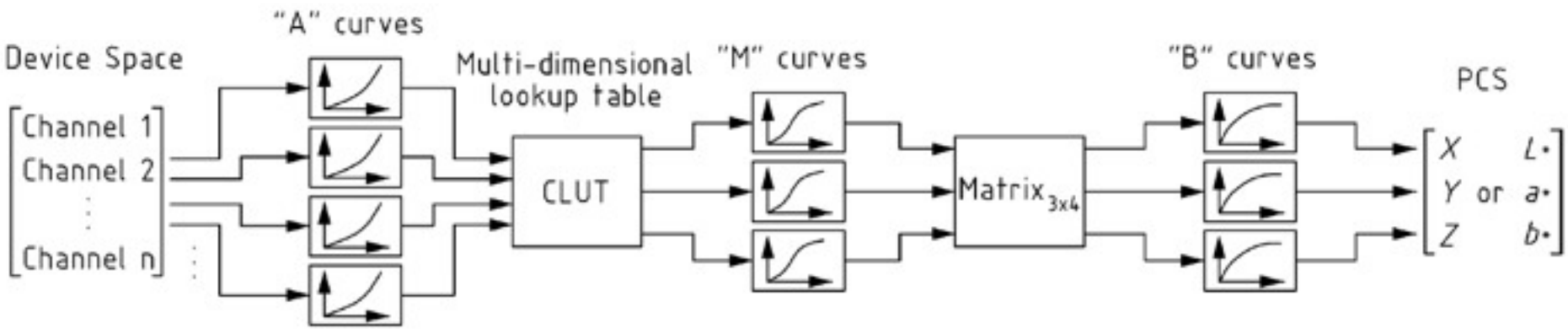
Profile Cache

- 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 dependent upon the source colorspace definition.
- Profiles are only released if we are at maximum number (or memory), new request is made and a Ref Count is zero.

Example PS CIEABC





DeviceN colour spaces (PDF and PS)

For DeviceN output, very simple to provide capability for n-color ICC profile.

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

For DeviceN input colour, XPS requires ICC profile. PDF and PS use an alternate tint transform. Ghostscript will provide capability to define N-colour ICC profile for DeviceN input colours to replace the alternate tint transform if desired.

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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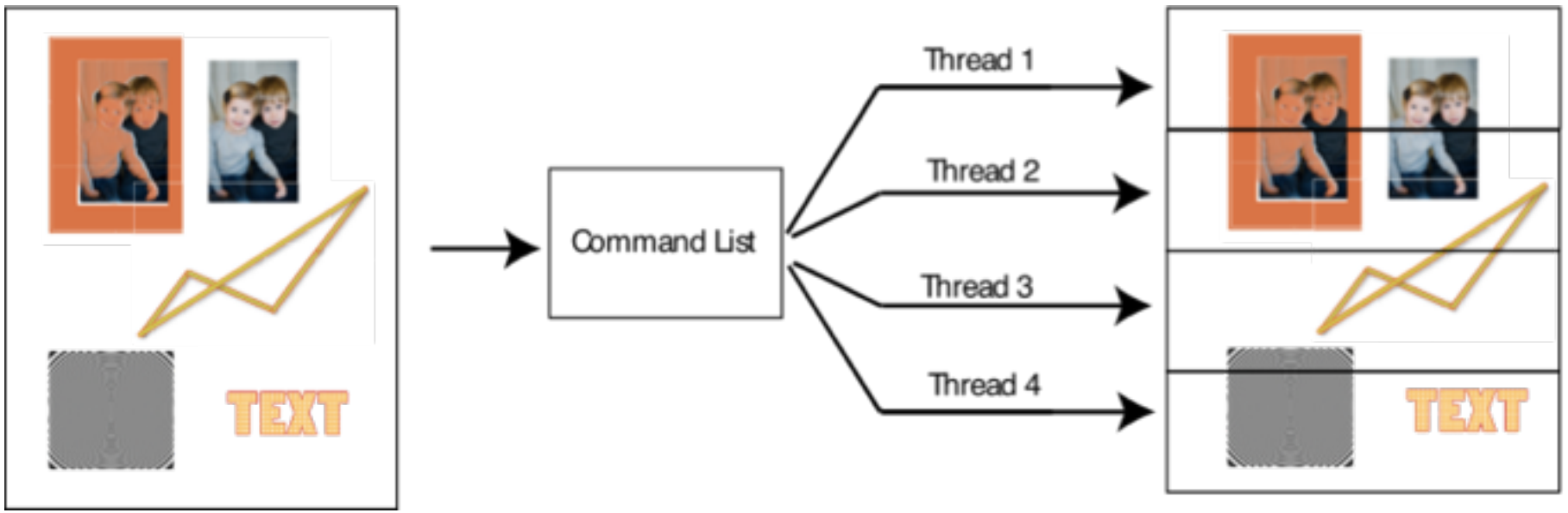
Ghostscript Multithreaded



Command List and ICC Profiles

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

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.
- It may be necessary to have a lock and release feature on the cache.
- If desired, a thread can start its own private link cache. This is similar to how each thread has its own evolving imaging state.
- It will be up to the thread to destroy the cache when it completes.

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Current Status

- ICC branch started in SVN.
  http://svn.ghostscript.com/ghostscript/branches/icc_work

- Currently interfacing to littleCMS http://www.littlecms.com/
  (Marti Maria).

- Code is almost complete. Reviewing regression differences.