

Experience with the color facsimile standard

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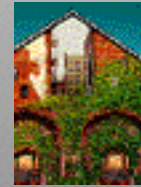
Outline

- Background for the standard
- Color representation and tolerances
- The color facsimile pipeline
- JPEG data compression
- The G3 facsimile protocol
- Prototype & timing
- Open issues



Four categories of business images

1. full color (pictorial, color photographs)



2. multi-color (color charts & graphs)



3. bi-color (documents marked up with red ink)



4. mixed color (combination of 1–3, such as color pages of magazines)

Source: NTT

Color space selection

17 spaces considered (Munsell, CMYK, YIQ, CIE colorimetric spaces)

Evaluation criteria (source: Fuji-Xerox):

- ability to represent all colors
- numerical complexity
- device independence
- quantization error under compression
- compatibility with compression algorithms
- color stability with white point change
- ...

Color space selected

- 1931 Standard Colorimetric Observer
- CIE Standard Illuminant D₅₀
- CIELAB color space
- Indirect handling of tolerances

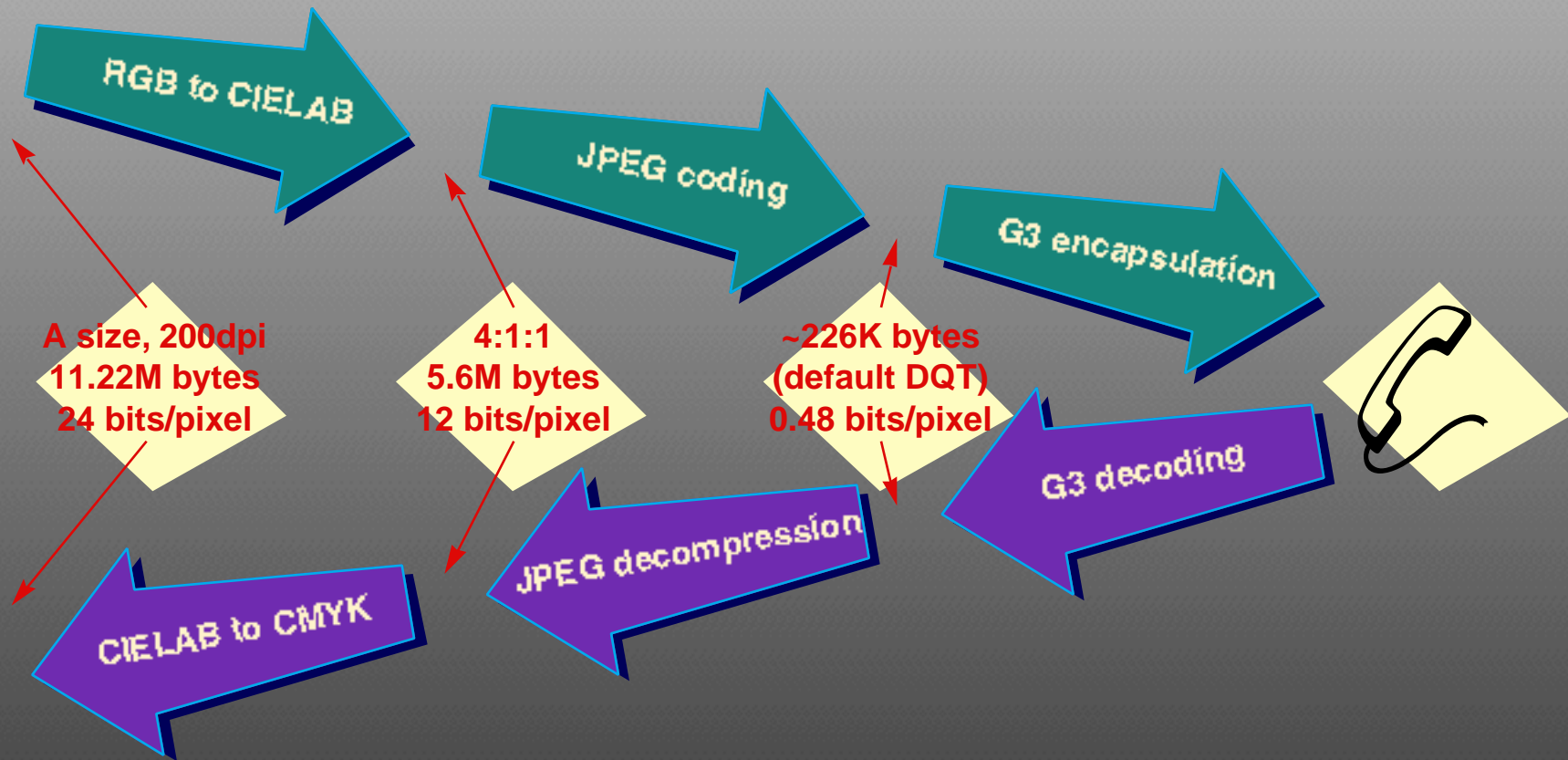
Color tolerances

Defined indirectly by prescribing the size of the gamut and number of bits used to represent coordinate values (8, optionally 12).

Defaults:

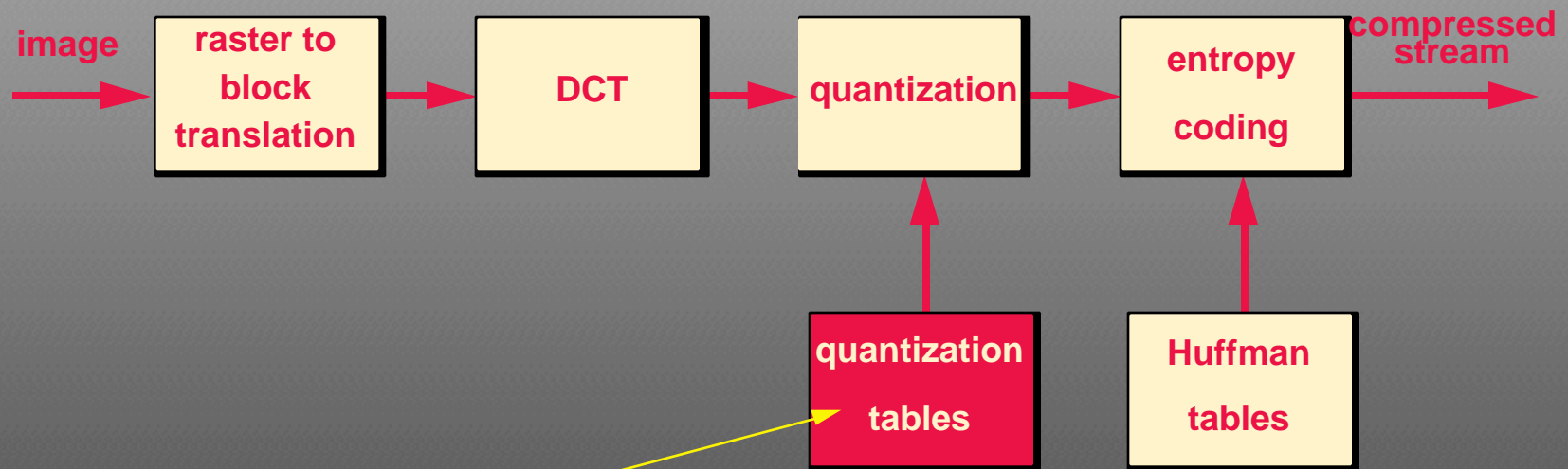
$$\begin{array}{ll} L^* & [0, 100] \\ \alpha^* & [-85, 85] \\ b^* & [-75, 125] \end{array} \quad \begin{array}{l} L = \frac{255}{100} L^* \\ a = \frac{255}{170} \alpha^* + 128 \\ b = \frac{255}{200} b^* + 96 \end{array}$$

Color facsimile pipeline



Data compression

ISO/IEC IS 10918-1 (a.k.a. JPEG)



“Critical knob”

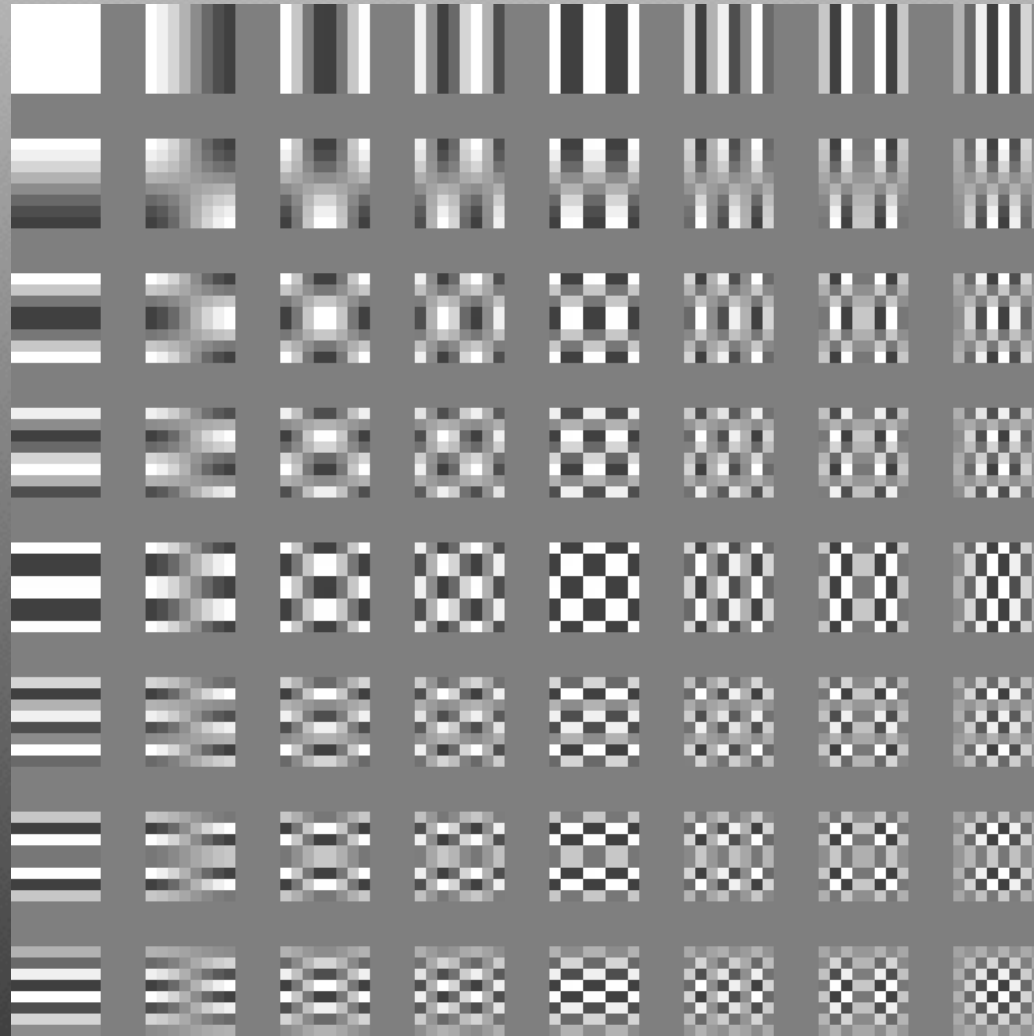
Discrete cosine transform

Discovered in 1974 by A. Ahmed, T. Natarajan, K.R. Rao

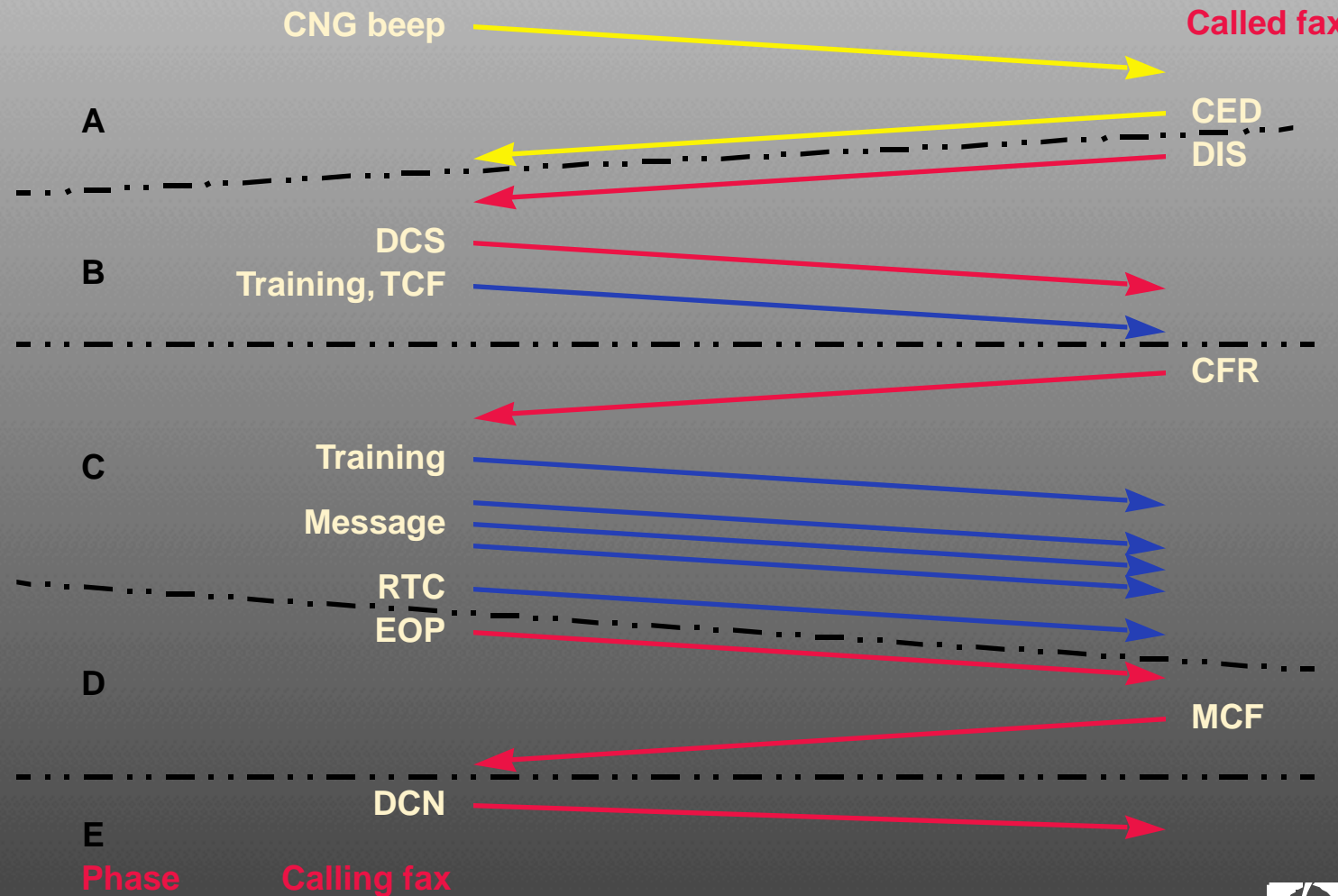
Benefits:

- real, separable, and orthogonal
- approaches KLT (Karhunen-Loeve transform, the statistically optimal transform)
- existence of fast algorithms

The DCT kernels



Time phases for T.30 fax transmission



The five T.30 time phases

1. *Call setup.* The connection is established and both parties agree they are facsimile machines. Send the CSI (Called Station Identifier).
2. *Pre-message procedure.* Callee sends DIS (digital identification signal) with receiving capabilities. Caller sends desired capabilities via a DCS (digital command signal). The transmission speed is trained.
3. *Message transmission.* The actual transmission of the facsimile.
4. *Post-message procedure.* Switch back to command mode (RTC, return to control) and confirm message (MCF, message confirmation).
5. *Call release.* Disconnect (DCN).

New G3 entries to DCS frames

Bit No.	DCS
68	JPEG coding
69	Full color mode
70	Preferred Huffman tables
71	12 bits/pel/component
72	Extend field
73	No subsampling (1:1:1)
74	Custom illuminant
75	Custom gamut range

Color facsimile prototype

HP Vectra 486/66XM PC with ScanJet IIc/ADF and DeskJet 660c



Compression ratio

Image	Default DQT	Custom DQT
Real estate flier with photo	52:1	82:1
Book page with photos and text	53:1	63:1
4CP01 test chart	47:1	63:1

Timing results

Subsystem	Min:Sec
Scanning (200 dpi)	0:44
Color transformations	0:45
Transmission (including handshaking, 9600 bps)	3:32
Compression (JPEG coding)	0:30
Printing (including halftoning, 200 dpi)	1:18

Open issues

- Design of good quantization tables is more an art than a science
- Colorimetric color reproduction is largely based on aperture colors
- Relation between JPEG quantization errors and color tolerances
- Trade-off between color tolerances and transmission times

Conclusions

- Group 3 fax protocol can be easily extended for color
- With the default tables, the compressed JPEG files are too large for practical commercial applications
- Need better understanding of spatial color perception
- Need method to characterize a system in terms of color tolerances