Implementing A Color Facsimile Machine

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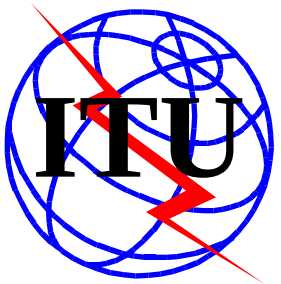
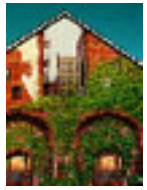
Outline

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

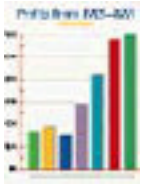


Four categories of business images

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
- …

Result of the color space evaluation

- 1931 Standard Colorimetric Observer
- CIE Standard Illuminant D_{50}
- CIELAB color space

Color coordinate representation

Number of bits used to represent coordinate values:
8, optionally 12.

Default gamut:

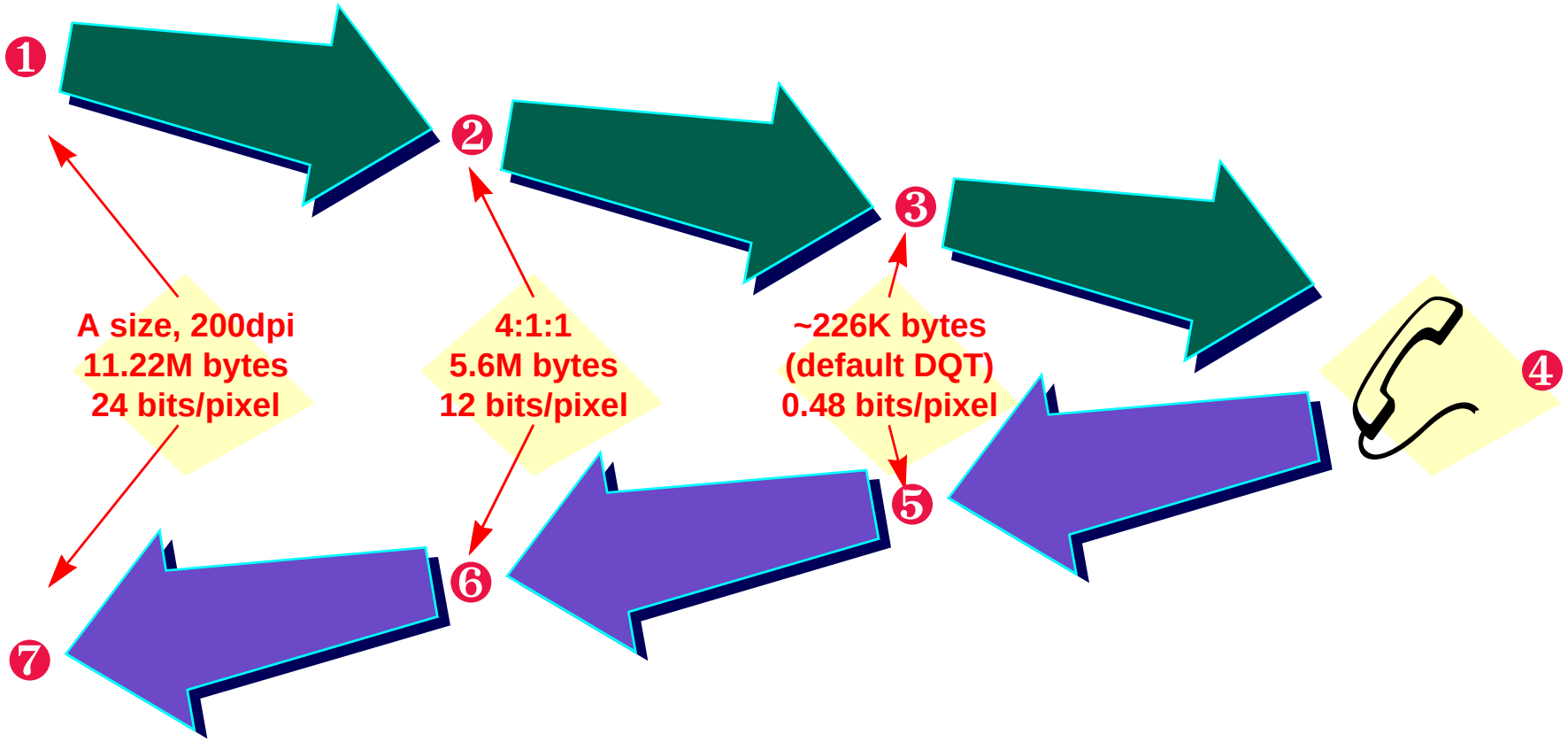
L^*	$[0, 100]$
a^*	$[-85, 85]$
b^*	$[-75, 125]$

$$L = \frac{255}{100} L^*$$

$$a = \frac{255}{170} a^* + 128$$

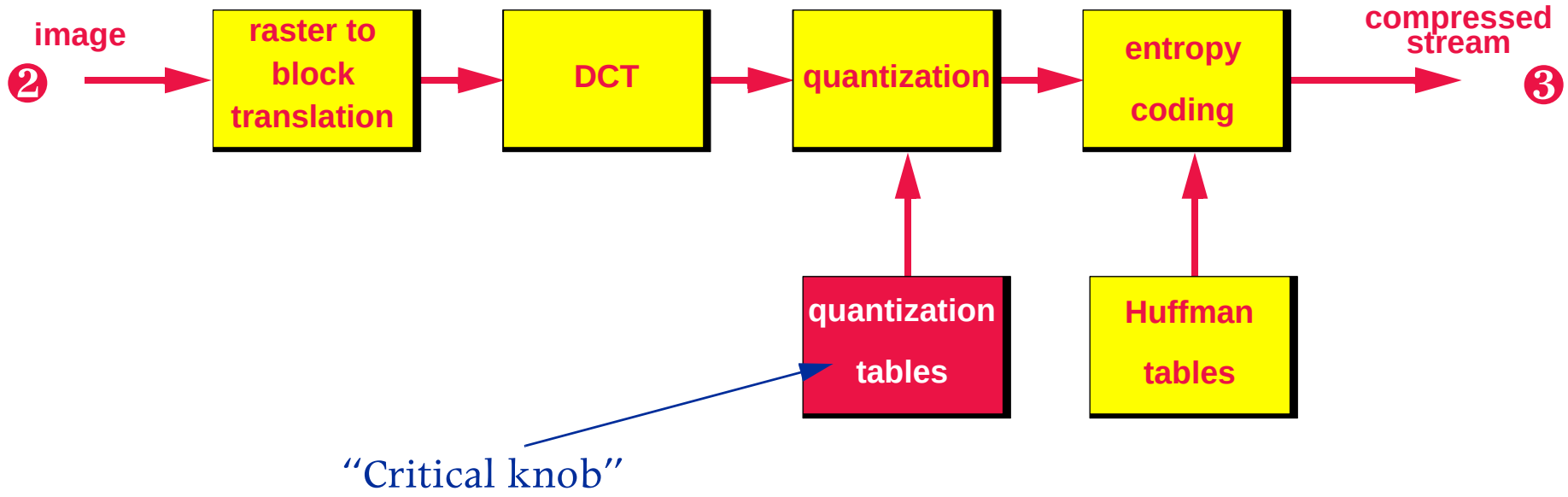
$$b = \frac{255}{200} b^* + 96$$

Color facsimile pipeline



Data compression

ISO/IEC IS 10918–1 (a.k.a. JPEG)



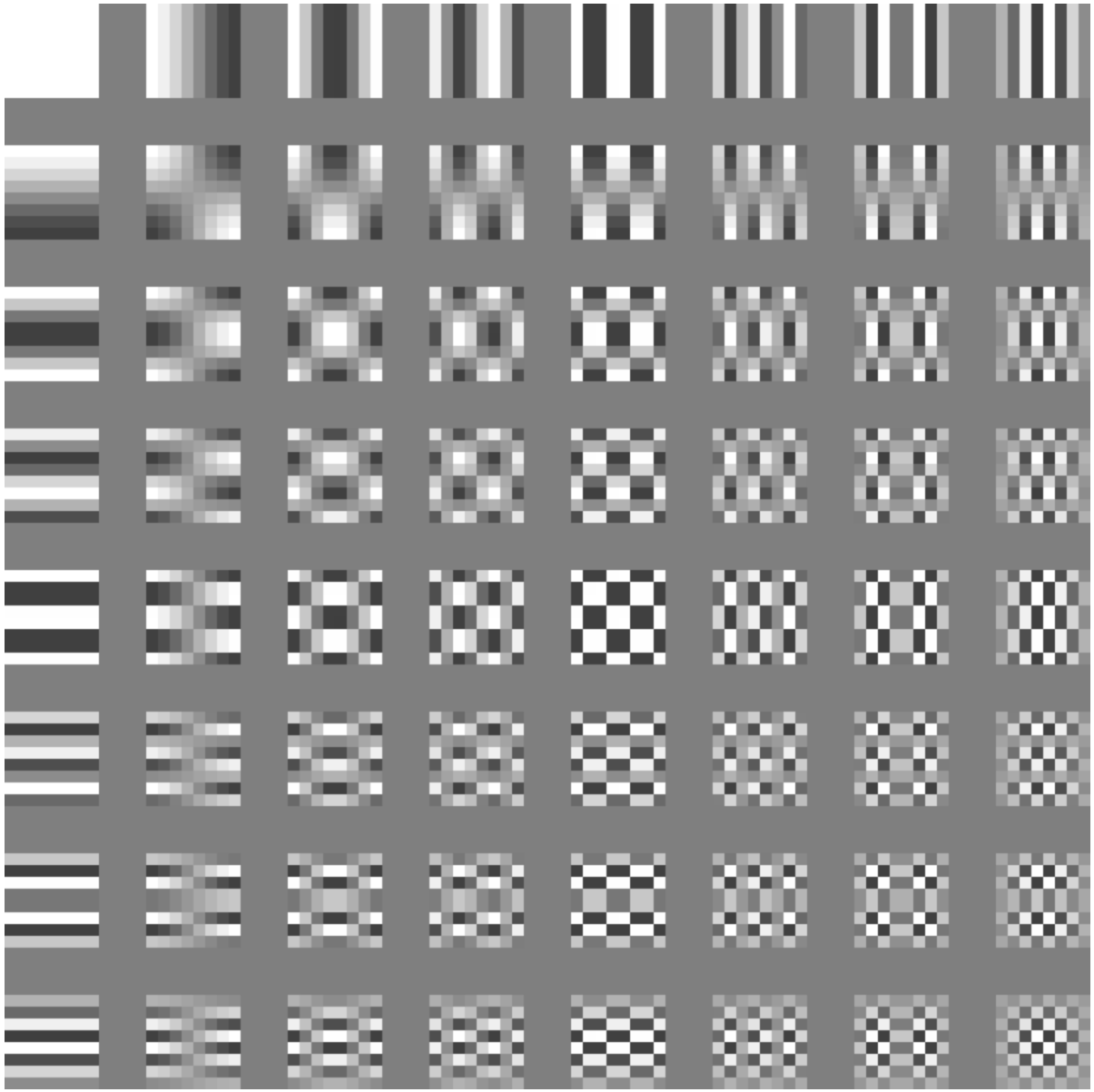
Discrete cosine transform

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

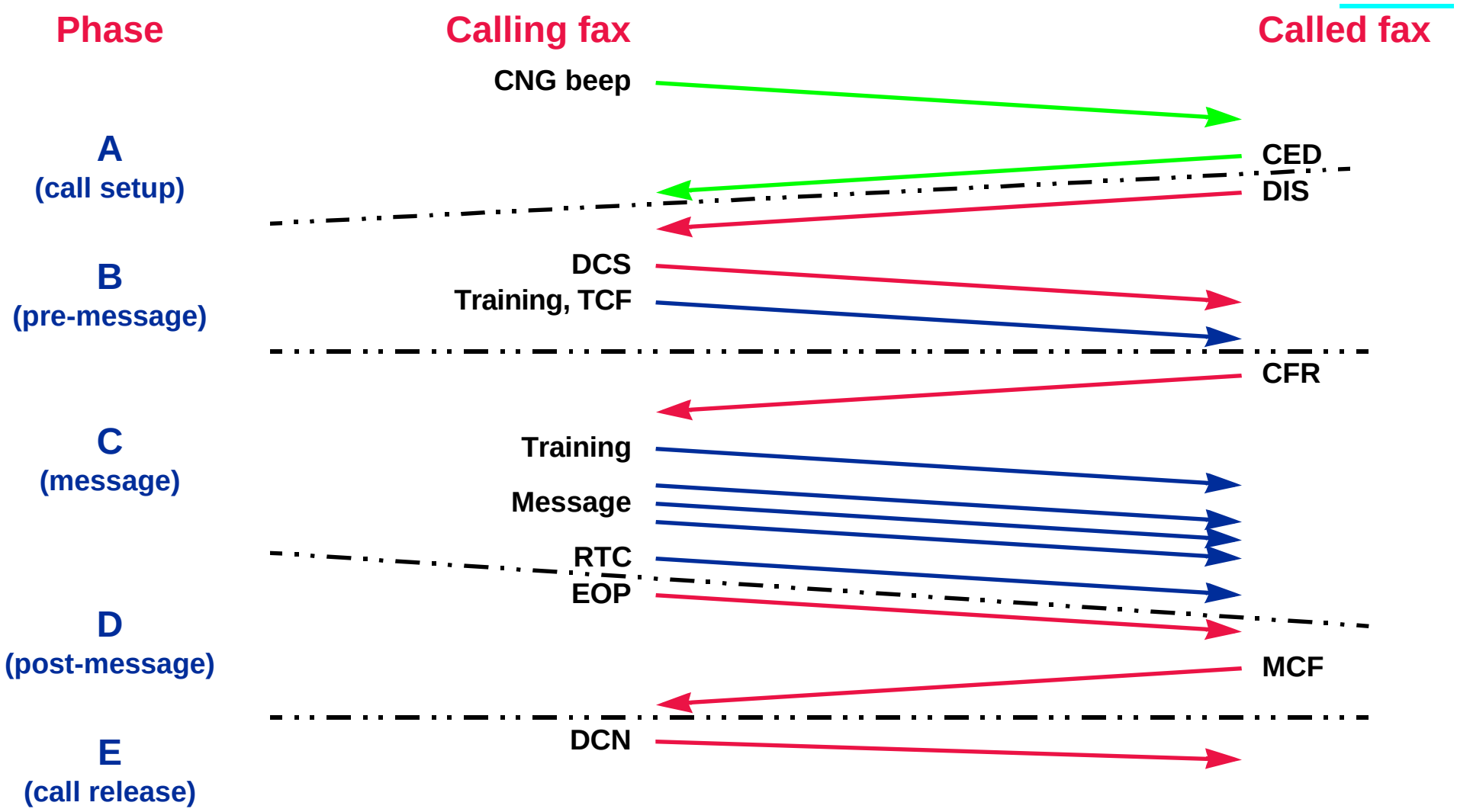
Benefits:

- 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.* Receiver 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 image.
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 (not used)
75	Custom gamut range

Protocol testing

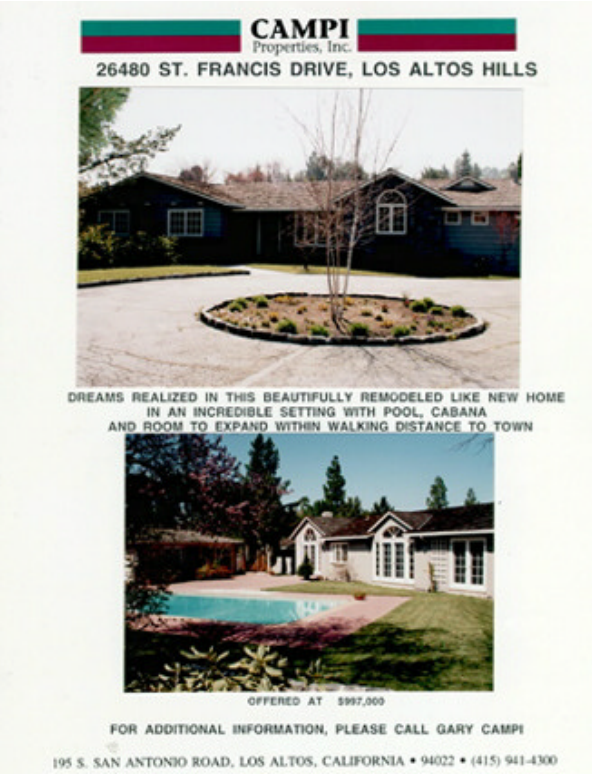
- Two independent implementations by different teams in different companies
- Software implementations on Vectra and Macintosh platforms
- Extensive downwards compatibility testing with existing Group 3 facsimile T.30 protocol
- No problems were found in the standard
- We learned where the pitfalls are, *e.g.*, no frame padding

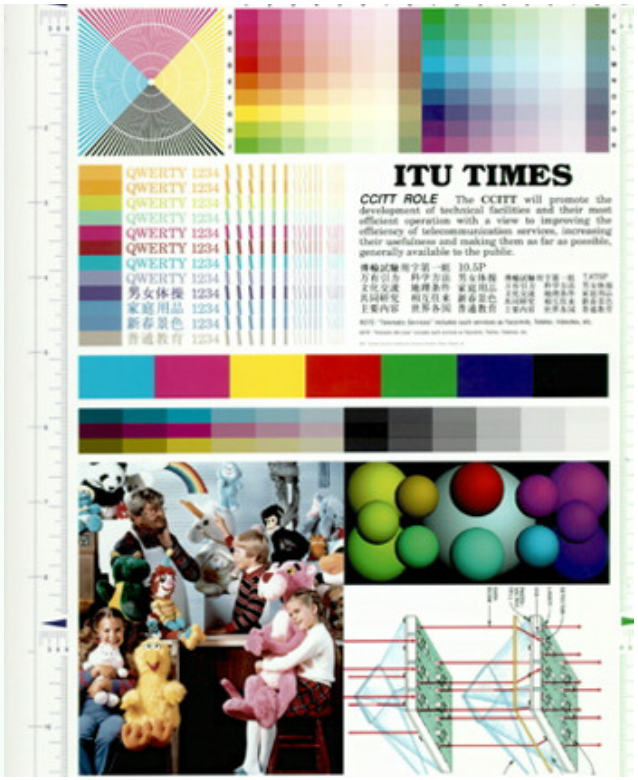
Color facsimile prototype

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

Compression ratio

Image (10.7M B)	Default DQT	Custom DQT
Real estate flier with photo	52:1 (211K B)	82:1 (134K B)
Book page with photos and text	53:1 (207K B)	63:1 (174K B)
4CP01 test chart	47:1 (233K B)	63:1 (174K B)





Timing results for 4CP01

Subsystem	Min:Sec
Scanning (200 dpi)	0:44
Color transformations	0:45
Compression (JPEG coding)	0:25
Transmission (including handshaking, 9600 bps)	2:48
Printing (including halftoning, 200 dpi)	1:18

By comparison, the transmission time with a conventional (1 bit black & white instead of 24 bit color) facsimile machine is 1:56 min:sec for scanning, compression, and transmission

Open issues

- Design of good quantization tables is more an art than a science
- Trade-off between image quality and transmission times
- Lossless compression mode (palettized color, continuous tone color, device-dependent color)
- Ability to specify an illuminant other than D_{50}

Conclusions

- Group 3 fax protocol can be easily extended for color
- With the default tables, the compressed JPEG files are larger than necessary
- Ongoing activity in ITU to extend the standard