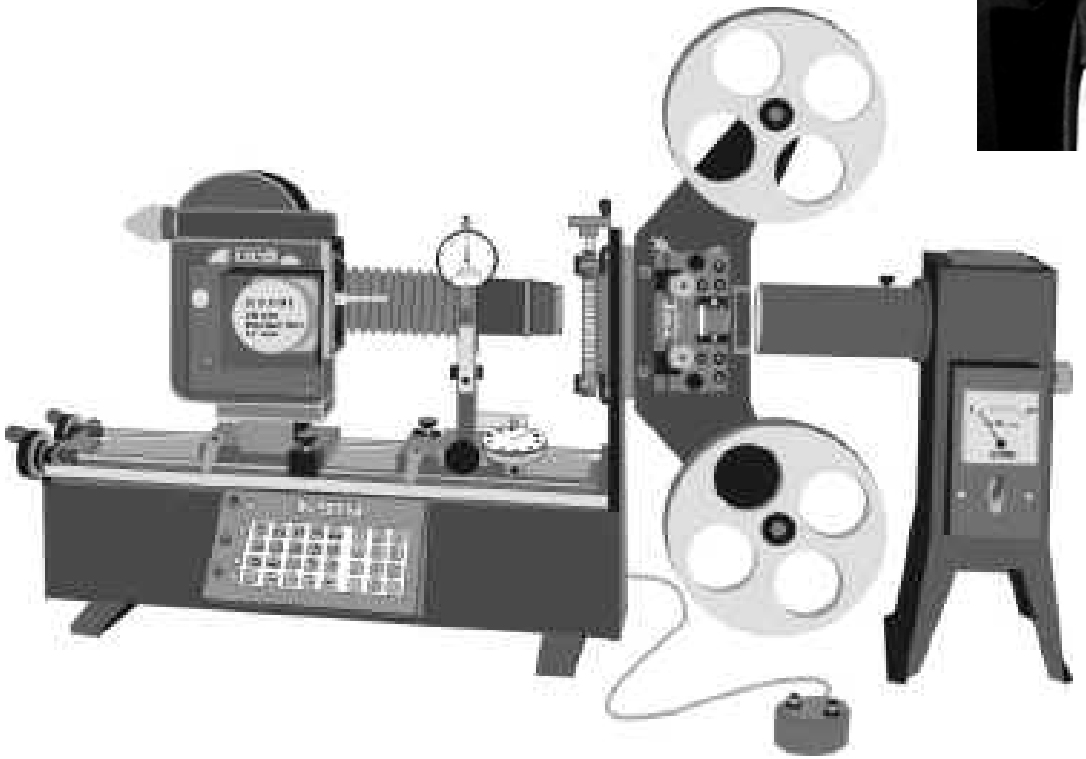
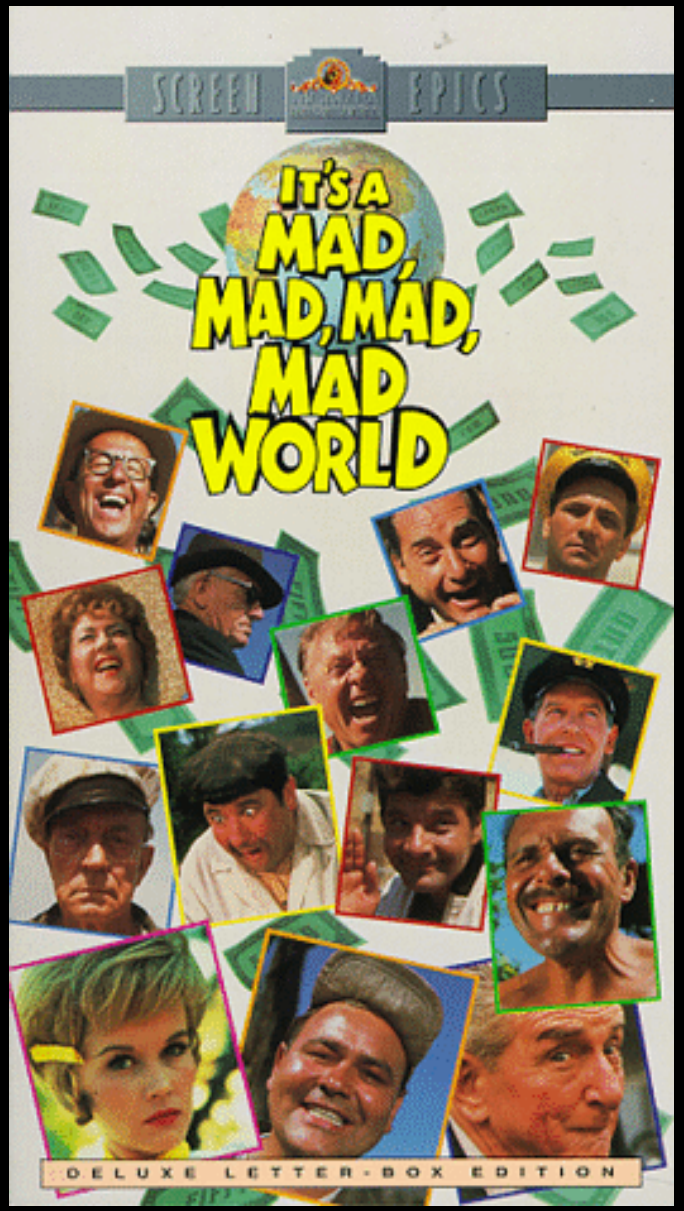
Lynwood Dunn (1904-1998)

- Visual effects pioneer
- Acme-Dunn optical printer




SCREEN
EPICS
IT'S A
MAD, MAD, MAD, MAD
WORLD
DELUXE LETTER-BOX EDITION


At the end of the universe
lies the beginning of vengeance.
STAR TREK II
THE WRATH OF KHAN

Academy of Motion Picture Arts & Sciences

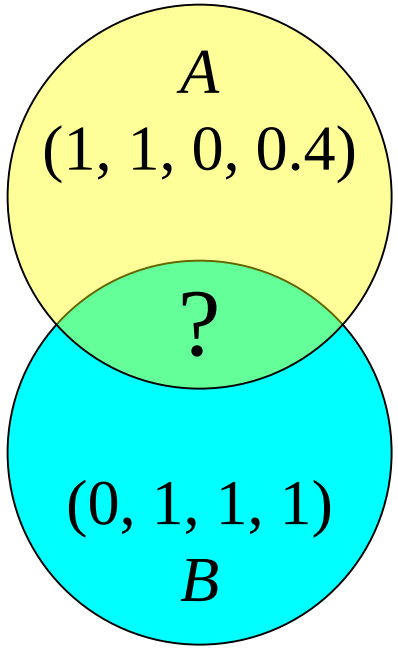
Scientific and Engineering Award

To Alvy Ray Smith, Tom Duff, Ed Catmull and Thomas Porter
for their Pioneering Inventions in Digital Image
COMPOSITING.

PRESENTED MARCH 2, 1996

The Over Operator

- How to indicate which parts of front picture are clear and which are opaque
- Alpha channel indicates opacity [Smith]
- Over operator [Porter & Duff S’84]



40% opaque yellow

100% opaque cyan

The Over Operator

- How to indicate which parts of front picture are clear and which are opaque
- Alpha channel indicates opacity [Smith]
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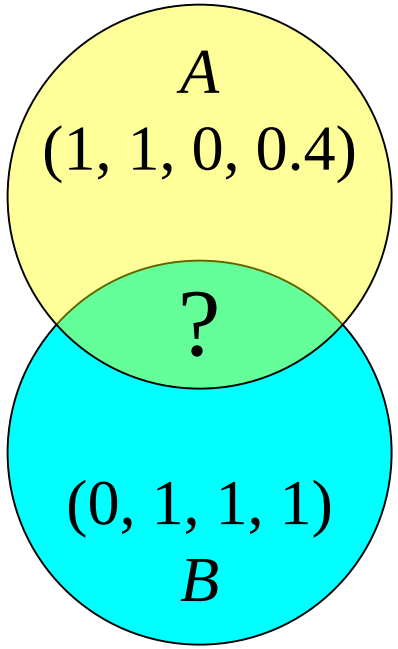


40% opaque yellow

100% opaque cyan

$(\alpha_B = 100\%)$

$C_{A \text{ over } B} = \alpha_A C_A + (1 - \alpha_A) C_B$

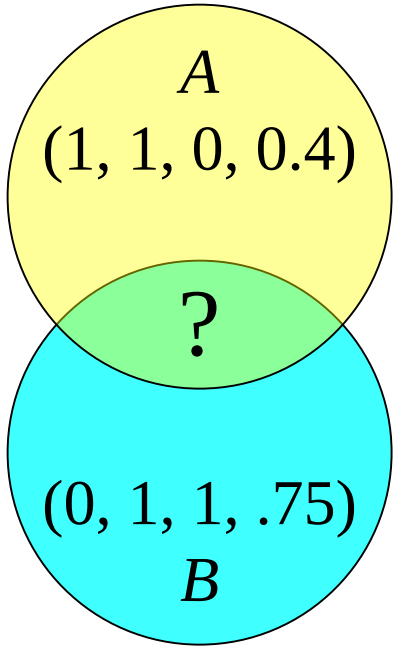
$= .4(1,1,0) + .6(0,1,1)$

$= (.4,1,.6)$

$\alpha_{A \text{ over } B} = 100\%$

The Over Operator

- But what if the result is not 100% opaque?



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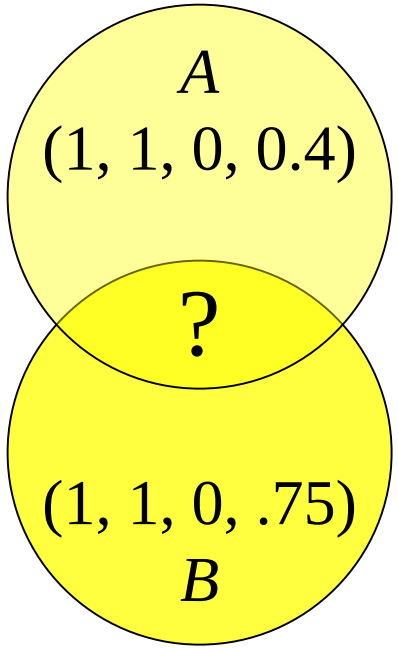
75% opaque cyan

The Over Operator

- But what if the result is not 100% opaque?
- For example, 40% opaque yellow over 75% opaque yellow should still yield yellow (1,1,0)
- But not at full opacity



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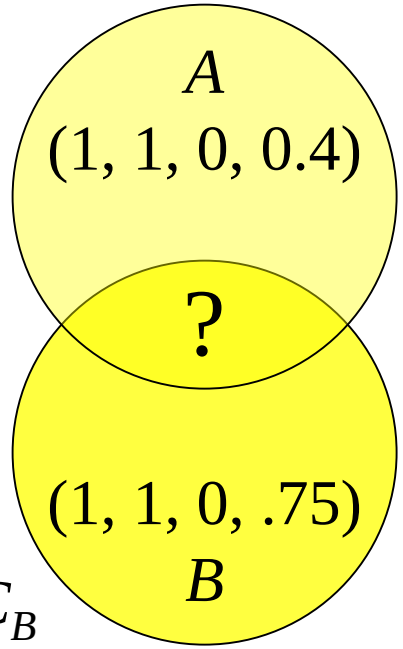
$$C_{A \text{ over } B} = \alpha_A C_A + (1 - \alpha_A)\, \alpha_B C_B$$



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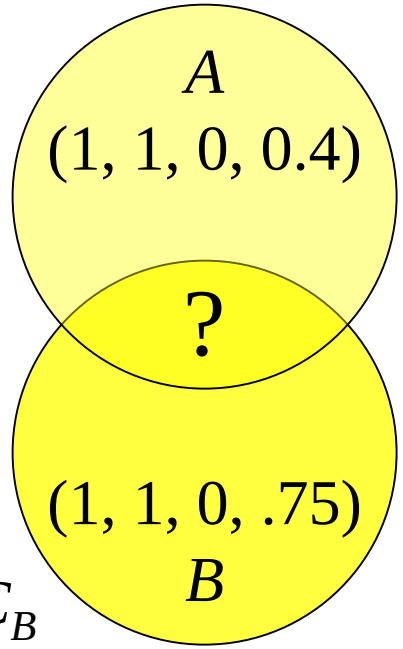

40% opaque yellow

75% opaque yellow

$C_{A \text{ over } B} = \alpha_A C_A + (1 - \alpha_A)\, \alpha_B C_B$

$= .4(1,1,0) + .6(.75)(1,1,0)$

$= (.85,.85,0)$ (!)

The Over Operator

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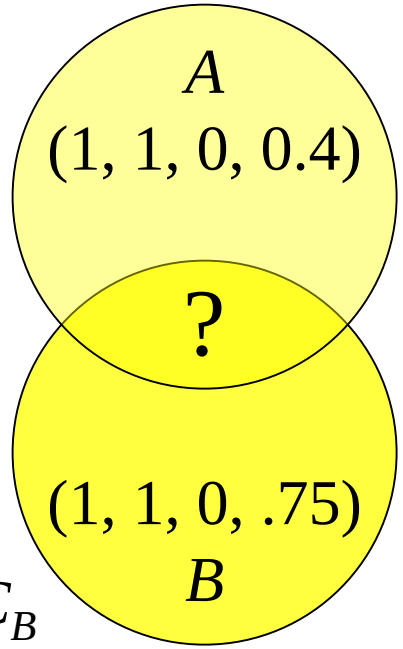

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$$= .4(1,1,0) + .6(.75)(1,1,0)$$
$$= (.85,.85,0)\ (!)$$

$$\alpha_{A \text{ over } B} = \alpha_A + (1 - \alpha_A)\, \alpha_B$$
$$= .4 + .6(.75)$$
$$= .85$$

The Over Operator

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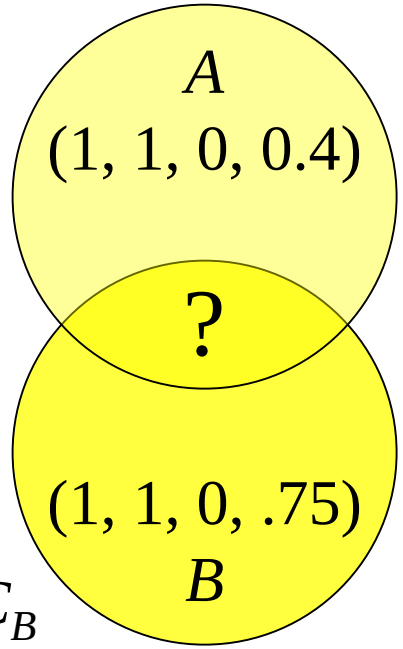

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$$= (.85,.85,0)\ (!)$$

$$\alpha_{A \text{ over } B} = \alpha_A + (1 - \alpha_A)\, \alpha_B$$
$$= .4 + .6(.75)$$
$$= .85$$

Need to divide $C_{A \text{ over } B}$ by $\alpha_{A \text{ over } B}$ to restore full color

Premultiplied Alpha

- Scale RGB by α

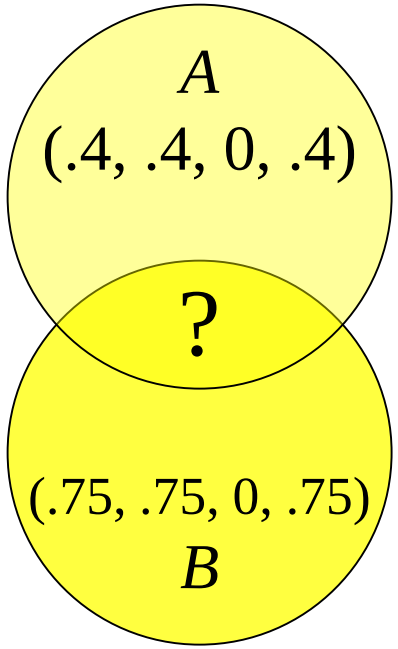
$$(\alpha R,\ \alpha G,\ \alpha B,\ \alpha)$$

- Homogenous color

- Premultiplied over operator

$$C_{A \text{ over } B} = C_A + (1 - \alpha_A)\, C_B$$

$$\alpha_{A \text{ over } B} = \alpha_A + (1 - \alpha_A)\, \alpha_B$$



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75% opaque yellow

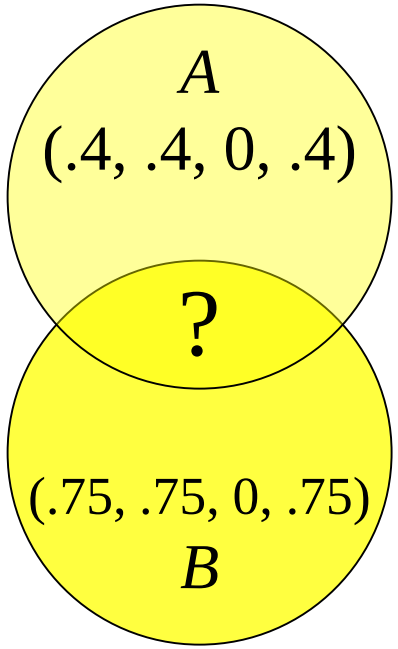
Premultiplied Alpha

- Scale RGB by α

  $(\alpha R,\ \alpha G,\ \alpha B,\ \alpha)$

- Homogenous color

- Premultiplied over operator



40% opaque yellow

75% opaque yellow

$$C_{A \text{ over } B} = C_A + (1 - \alpha_A)\, C_B$$
$$= (.4,.4,0) + .6\ (.75,.75,0)$$
$$= (.85,.85,0)$$

$$\alpha_{A \text{ over } B} = \alpha_A + (1 - \alpha_A)\, \alpha_B$$
$$= .4 + .6(.75)$$
$$= .85$$

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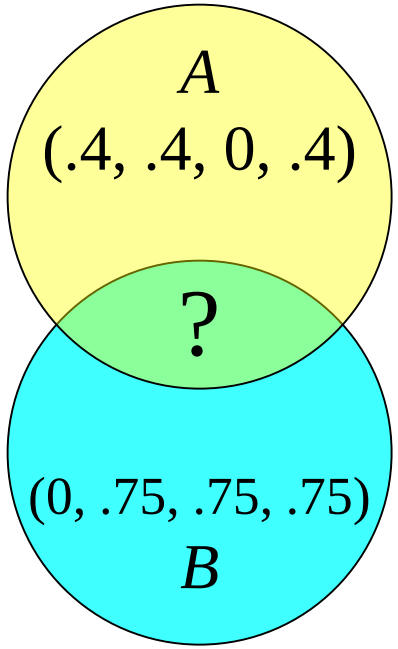


40% opaque yellow

75% opaque cyan

$$C_{A \text{ over } B} = C_A + (1 - \alpha_A)\, C_B$$
$$= (.4,.4,0) + .6\ (0,.75,.75)$$
$$= (.4,.85,.45)$$

$$\alpha_{A \text{ over } B} = \alpha_A + (1 - \alpha_A)\, \alpha_B$$
$$= .4 + .6(.75)$$
$$= .85$$

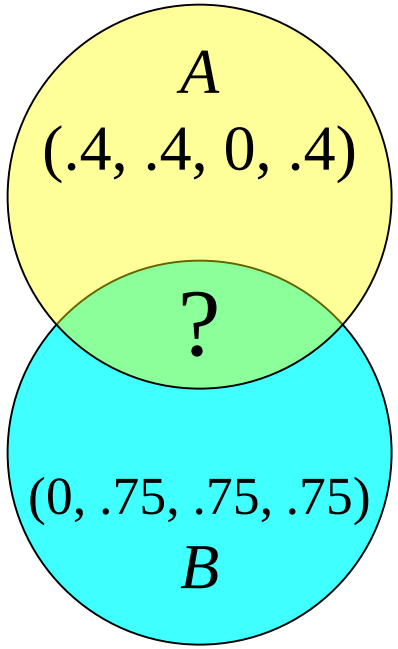
Premultiplied Alpha

- Scale RGB by α

  $(\alpha R,\ \alpha G,\ \alpha B,\ \alpha)$

- Homogenous color

- Premultiplied over operator



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$$C_{A \text{ over } B} = C_A + (1 - \alpha_A)\, C_B$$
$$= (.4,.4,0) + .6\ (0,.75,.75)$$
$$= (.4,.85,.45)$$
$$= .85(.47,1,.53)$$

$$\alpha_{A \text{ over } B} = .85$$