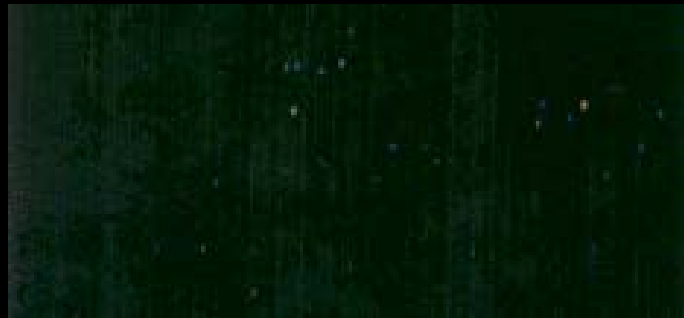


Lynwood Dunn (1904-1998)

- Visual effects pioneer
- Acme-Dunn optical printer





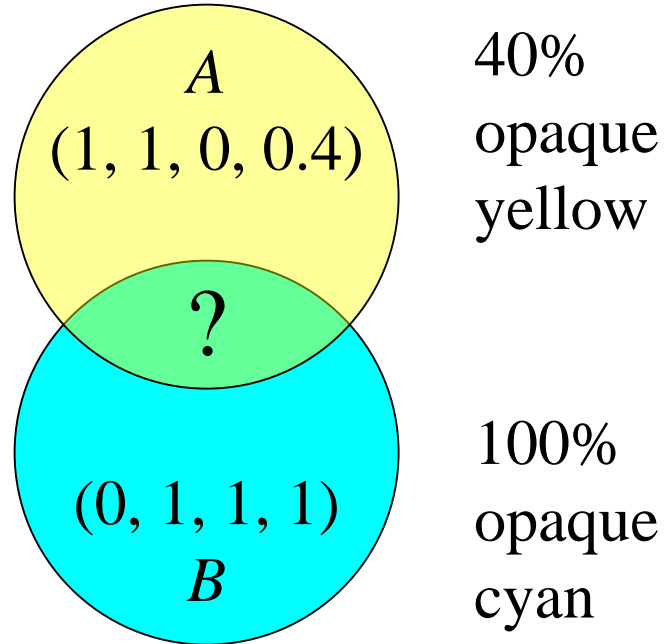




Academy of Motion Picture Arts & Sciences
Scientific and Engineering Award
To Alvy Ray Smith, Tom Duff, Ed Catmull and Thomas Porter
for their Pioneering Inventions in Digital Image
COMPOSITING.
PRESENTED MARCH 2, 1996

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]



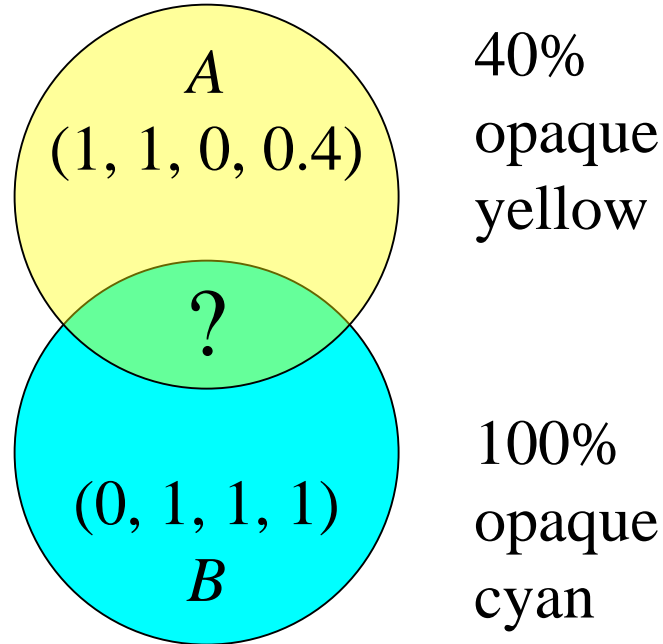
The Over Operator

- 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]

$$(\alpha_B = 100\%)$$

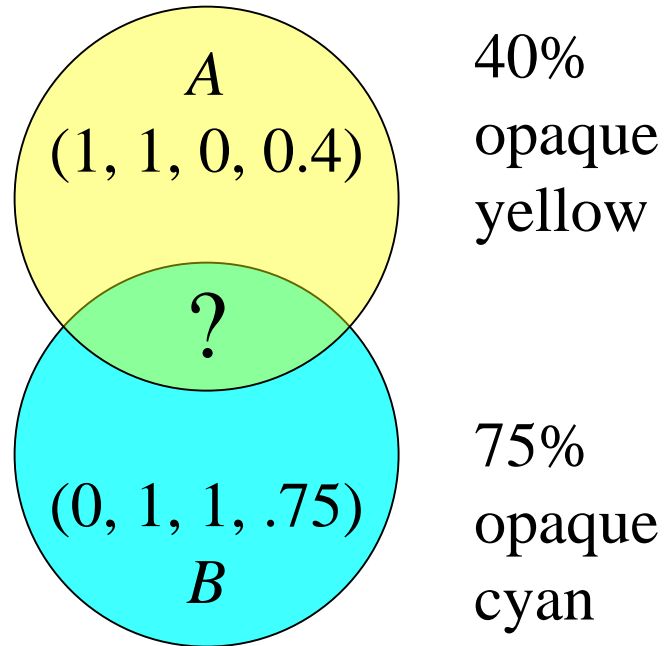
$$\begin{aligned} C_{A \text{ over } B} &= \alpha_A C_A + (1 - \alpha_A) C_B \\ &= .4(1,1,0) + .6(0,1,1) \\ &= (.4, 1, .6) \end{aligned}$$

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



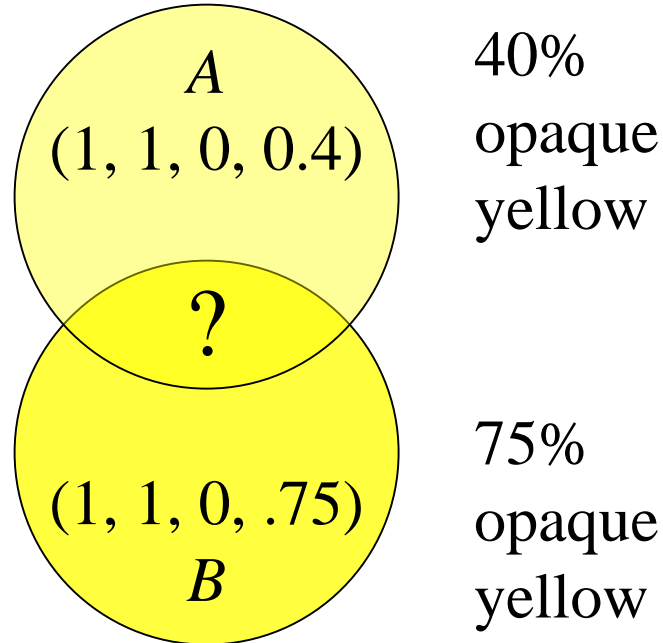
The Over Operator

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



The Over Operator

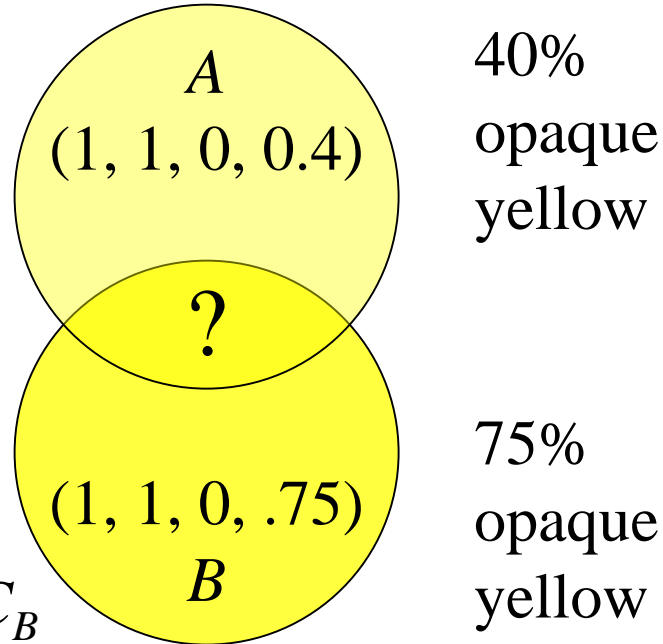
- But what if the result is not 100% opaque?
- For example, 40% opaque yellow over 75% opaque yellow should still yield yellow (1,1,0)
- But not at full opacity



The Over Operator

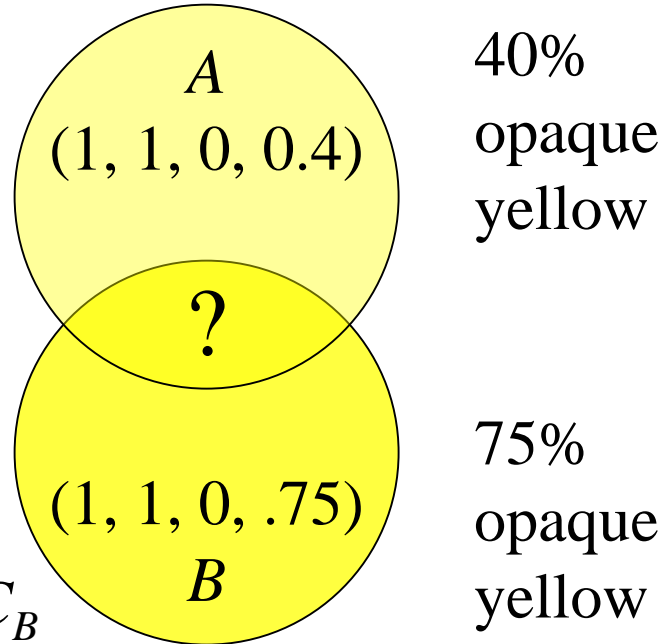
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$$C_{A \text{ over } B} = \alpha_A C_A + (1 - \alpha_A) \alpha_B C_B$$



The Over Operator

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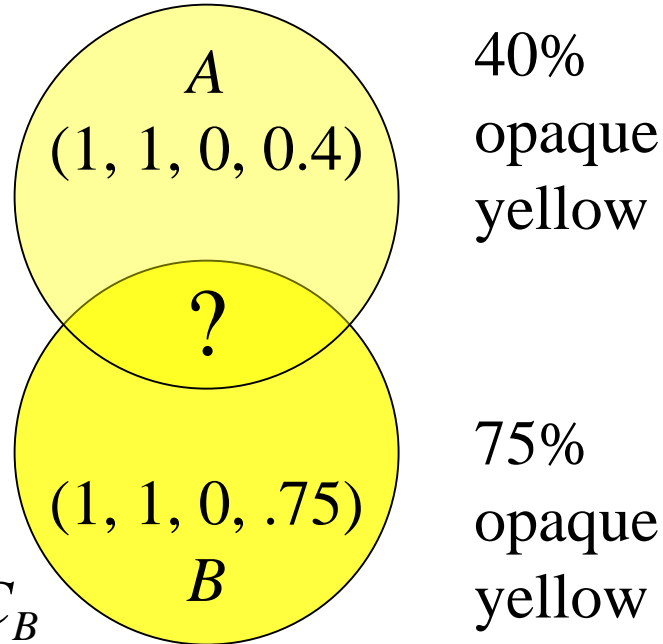
40%
opaque
yellow

75%
opaque
yellow

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

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)
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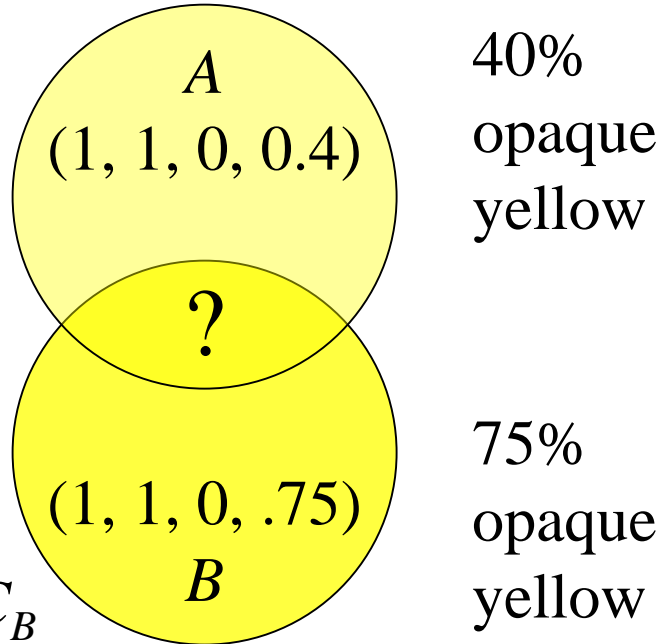


$$\begin{aligned}C_{A \text{ over } B} &= \alpha_A C_A + (1 - \alpha_A) \alpha_B C_B \\ &= .4(1,1,0) + .6(.75)(1,1,0) \\ &= (.85, .85, 0) (!)\end{aligned}$$

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

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

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

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

Premultiplied Alpha

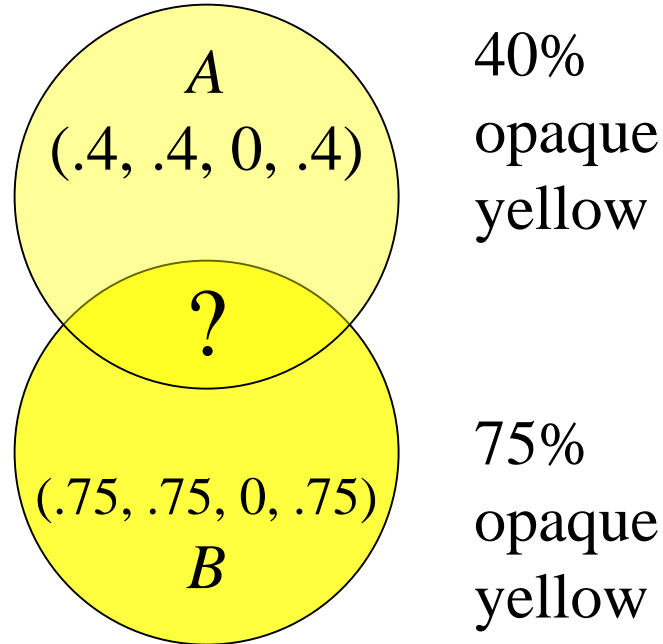
- Scale RGB by α
 $(\alpha R, \alpha G, \alpha B, \alpha)$

- Homogenous color

- Premultiplied over operator

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

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



Premultiplied Alpha

- Scale RGB by α

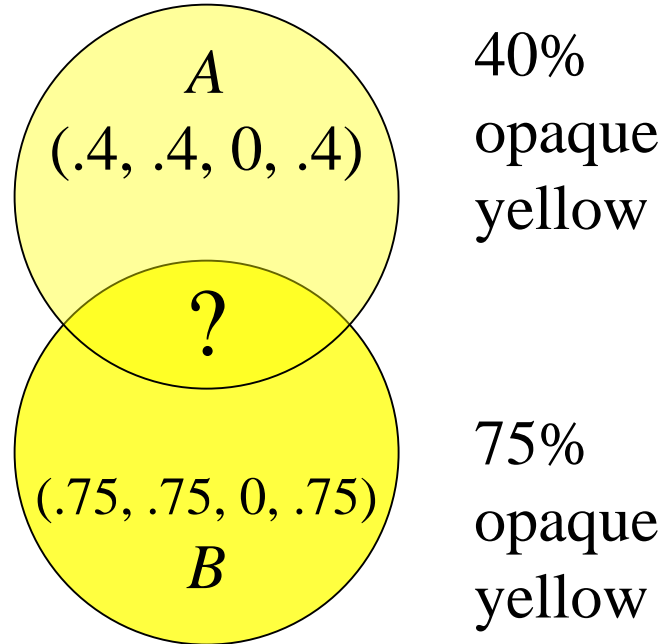
$$(\alpha R, \alpha G, \alpha B, \alpha)$$

- Homogenous color

- Premultiplied over operator

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

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



Premultiplied Alpha

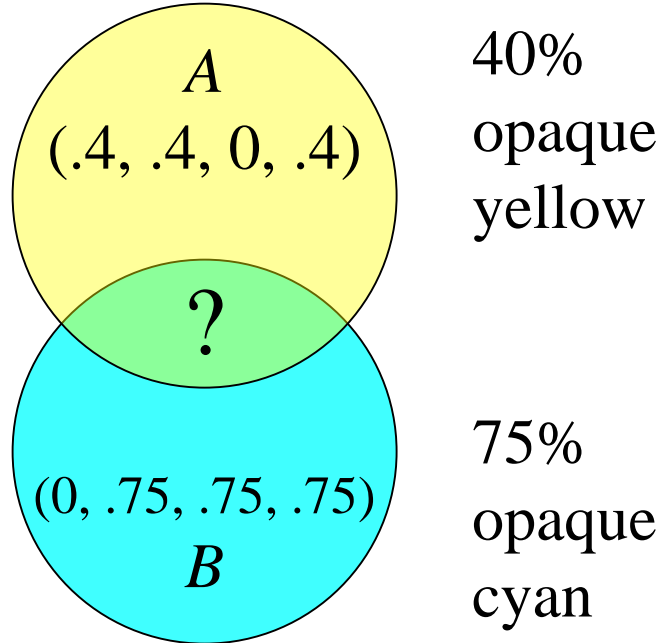
- Scale RGB by α
 $(\alpha R, \alpha G, \alpha B, \alpha)$

- Homogenous color

- Premultiplied over operator

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

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



Premultiplied Alpha

- Scale RGB by α
 $(\alpha R, \alpha G, \alpha B, \alpha)$

- Homogenous color

- Premultiplied over operator

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

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

