

# Lynwood Dunn (1904-1998)

- Visual effects pioneer
- Acme-Dunn optical printer







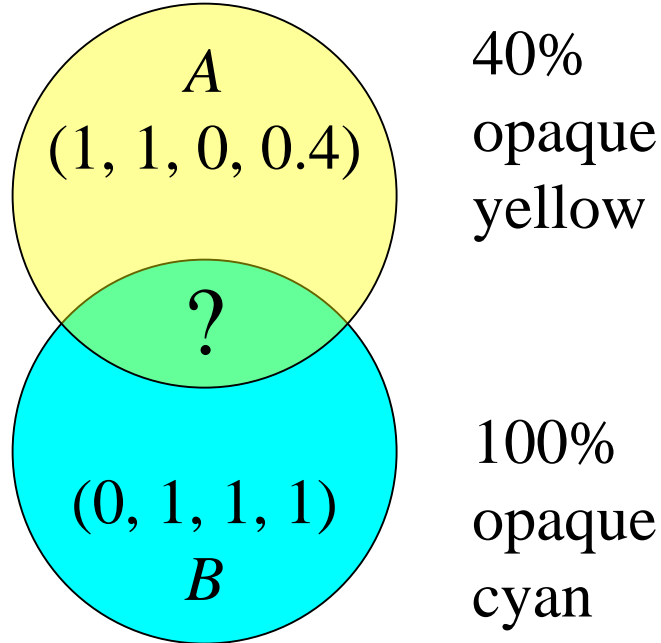




Academy of Motion Picture Arts & Sciences  
Scientific and Engineering Award  
To Alvy Ray Smith, Tom Duff, Ed Catmull and Thomas Porter  
for their Pioneering Inventions in Digital Image  
COMPOSITING.  
PRESENTED MARCH 2, 1996

# 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]



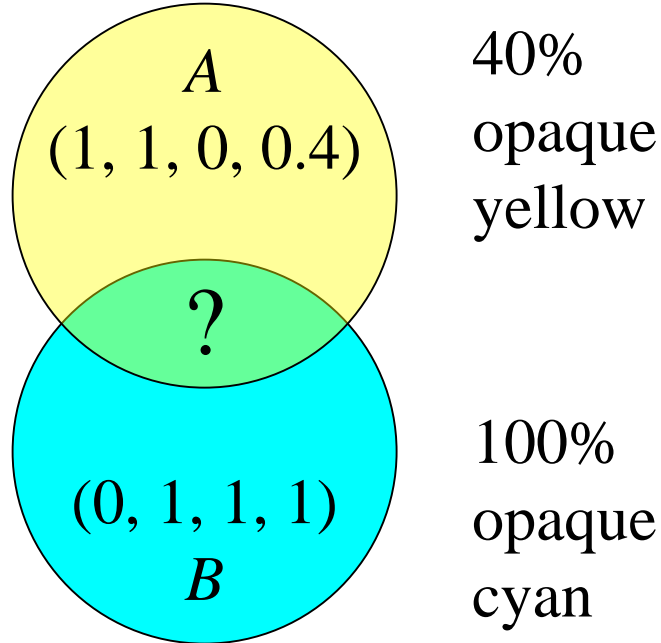
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- Over operator [Porter & Duff S'84]

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

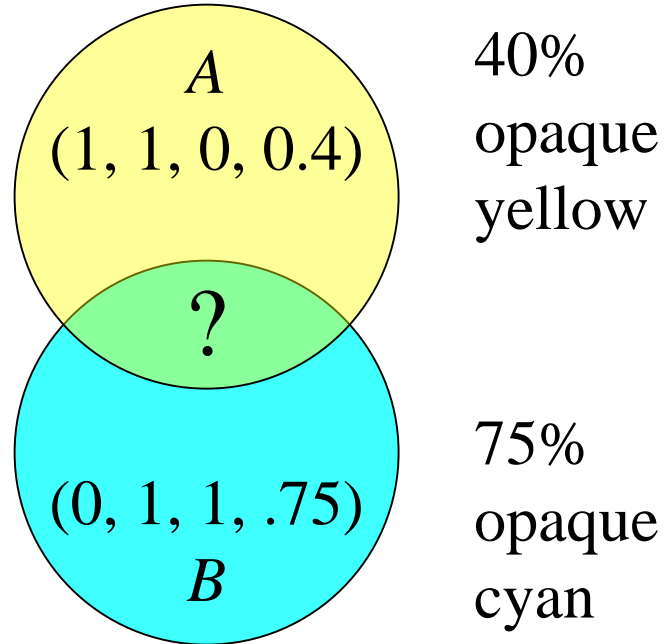
$$\begin{aligned} C_{A \text{ over } B} &= \alpha_A C_A + (1 - \alpha_A) C_B \\ &= .4(1,1,0) + .6(0,1,1) \\ &= (.4, 1, .6) \end{aligned}$$

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



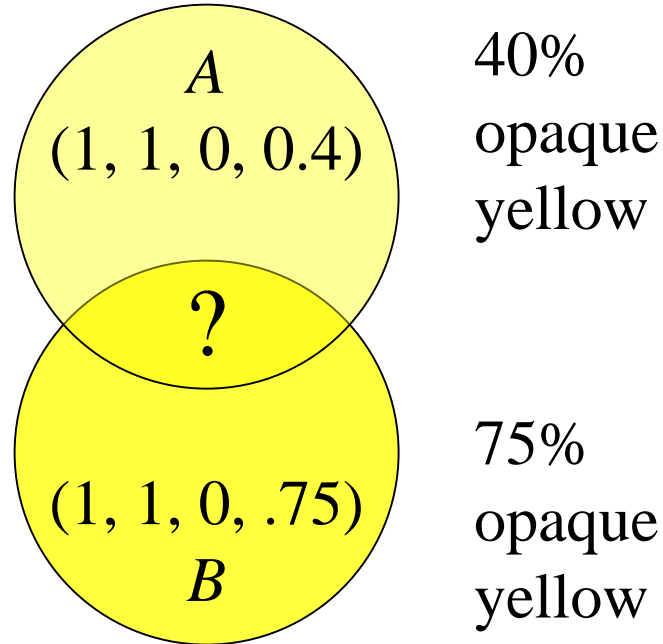
# The Over Operator

- 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

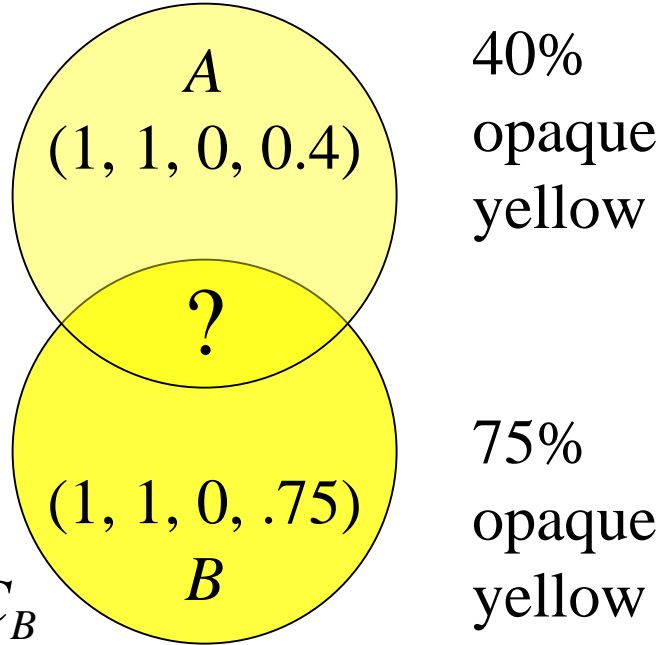




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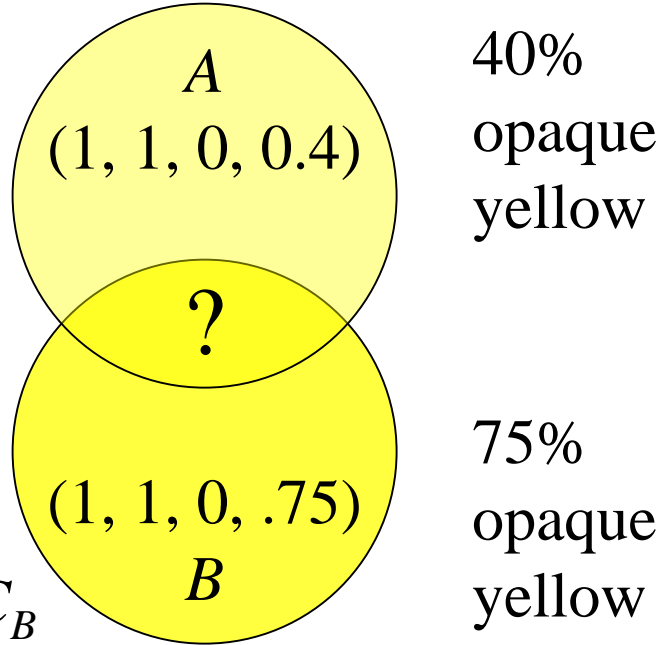
$$C_{A \text{ over } B} = \alpha_A C_A + (1 - \alpha_A) \alpha_B C_B$$



# The Over Operator

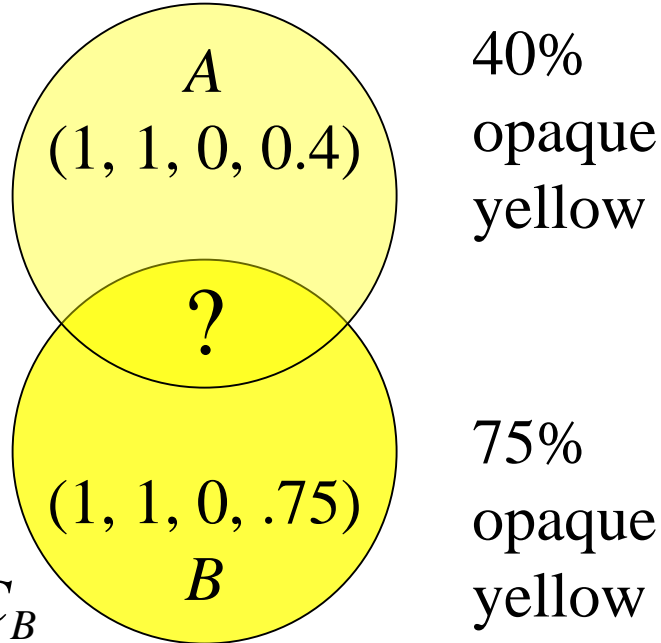
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$$\begin{aligned}C_{A \text{ over } B} &= \alpha_A C_A + (1 - \alpha_A) \alpha_B C_B \\&= .4(1,1,0) + .6(.75)(1,1,0) \\&= (.85,.85,0) (!)\end{aligned}$$



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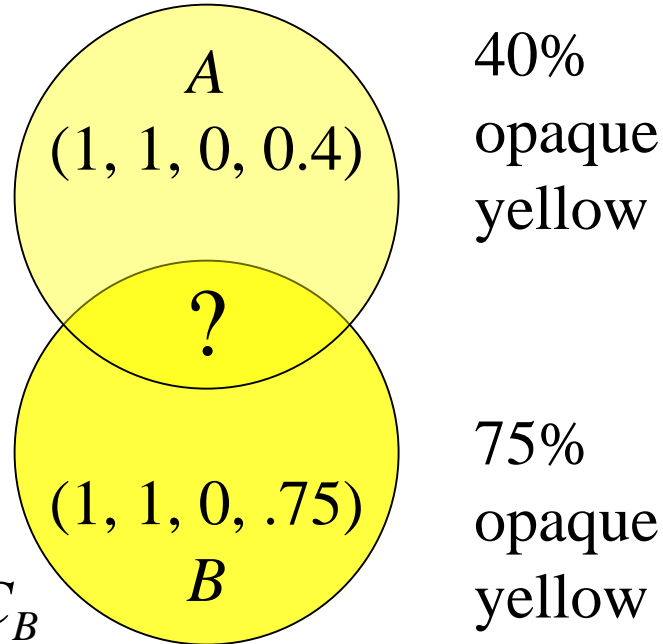


$$\begin{aligned}C_{A \text{ over } B} &= \alpha_A C_A + (1 - \alpha_A) \alpha_B C_B \\&= .4(1,1,0) + .6(.75)(1,1,0) \\&= (.85, .85, 0) (!)\end{aligned}$$

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

# The Over Operator

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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  $\alpha$

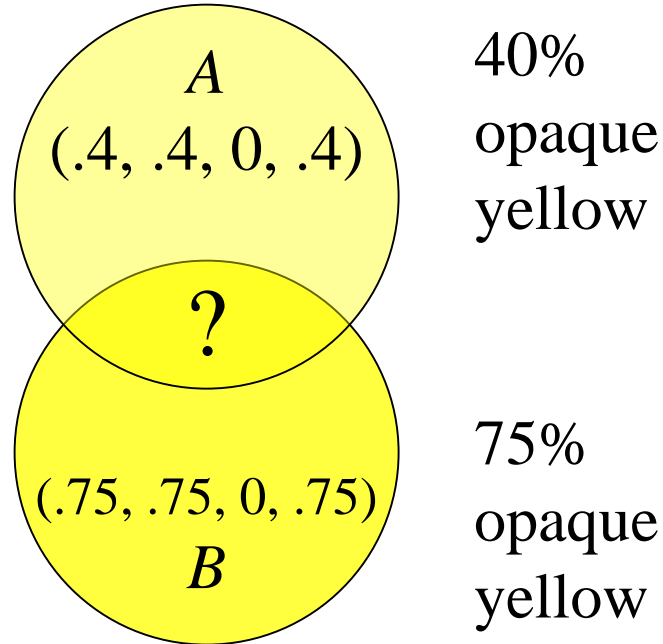
$$(\alpha R, \alpha G, \alpha B, \alpha)$$

- 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  $\alpha$

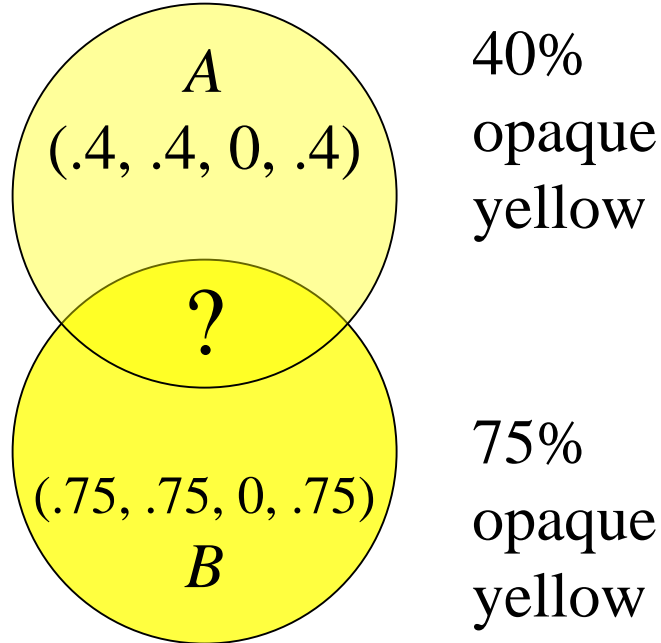
$$(\alpha R, \alpha G, \alpha B, \alpha)$$

- 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

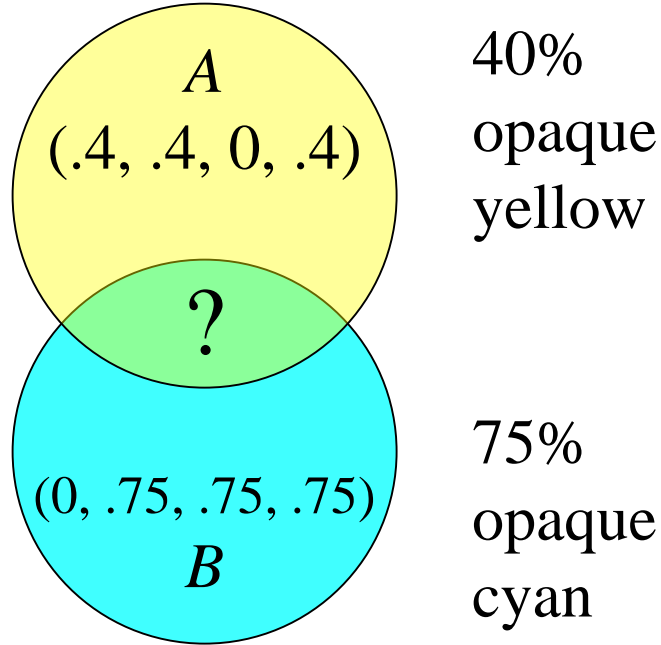
- Scale RGB by  $\alpha$   
 $(\alpha R, \alpha G, \alpha B, \alpha)$

- 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  $\alpha$

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

- Homogenous color

- Premultiplied over operator

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

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

