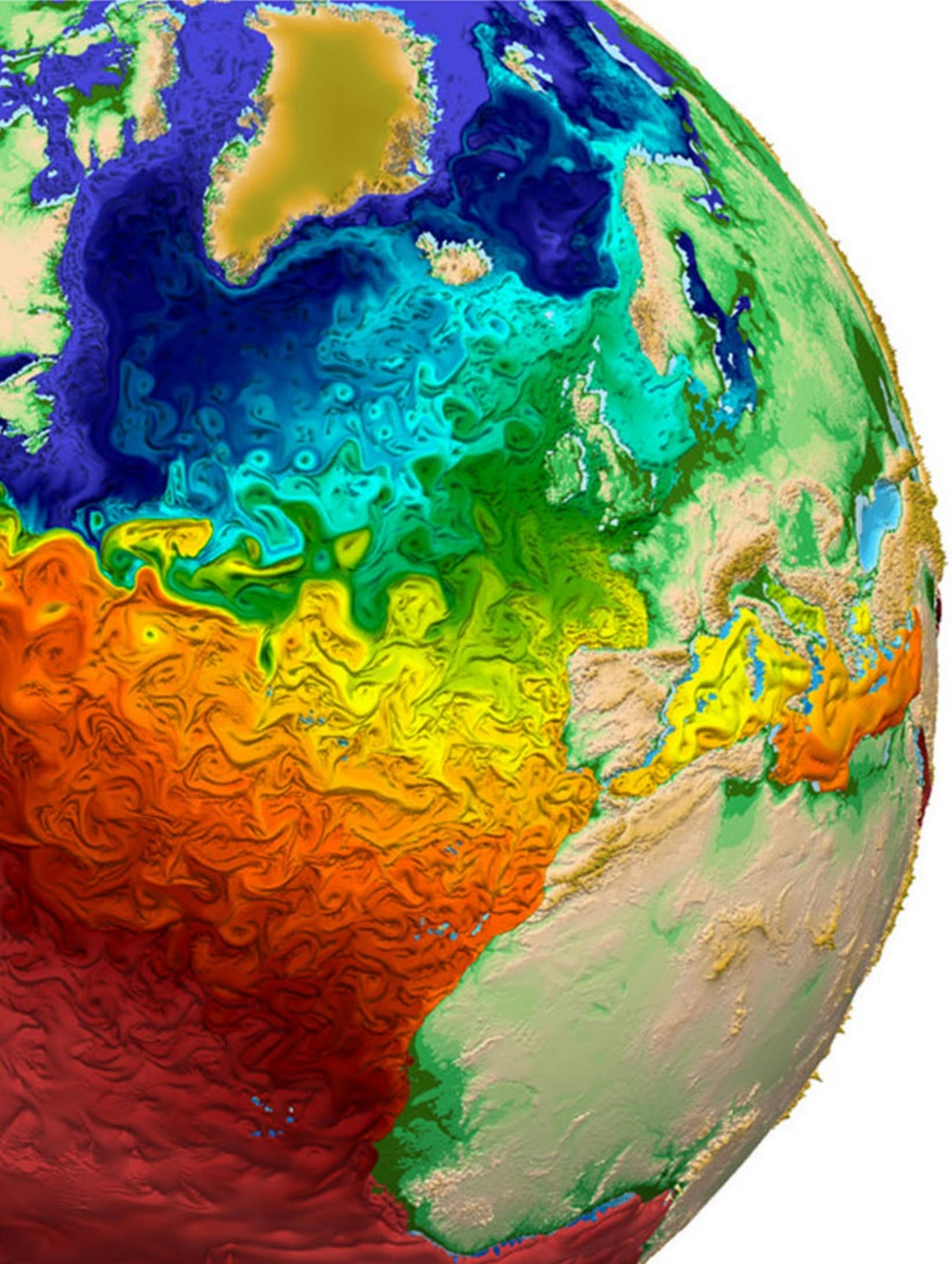


Volume Rendering

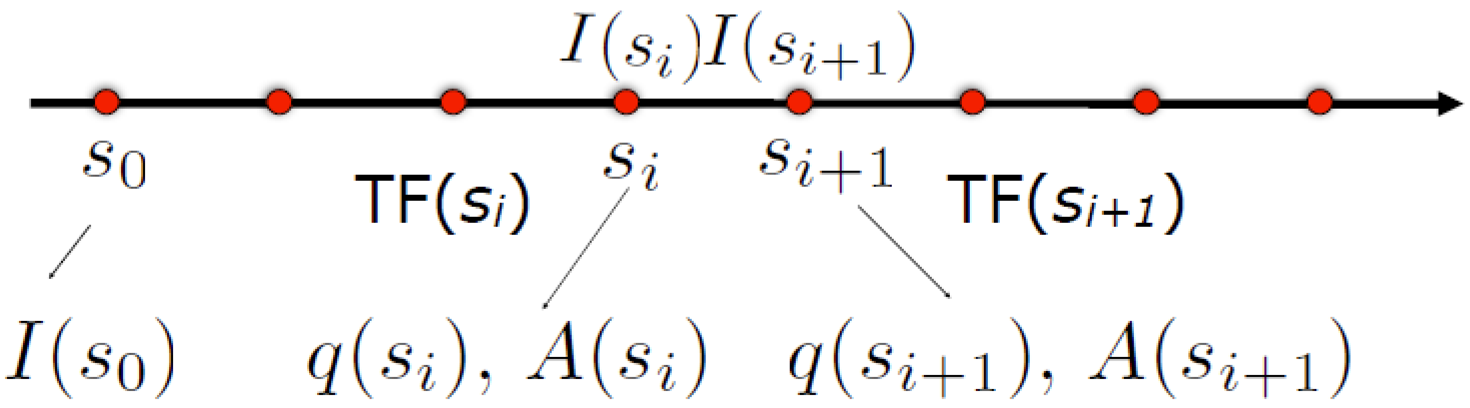
Compositing

Scientific Visualization

Professor Eric Shaffer

ILLINOIS

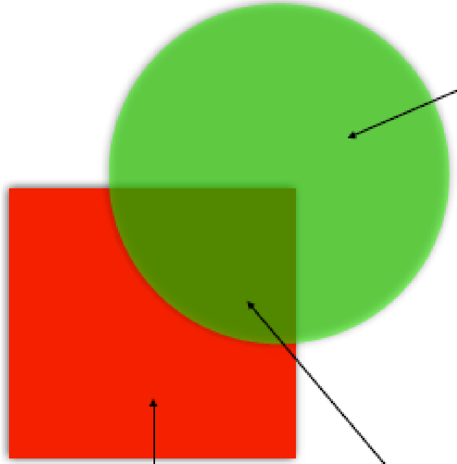
Approximating the Volume Rendering Integral



Back-to-front Compositing with $\alpha = A(s_{i+1})$

$$I(s_{i+1}) = \alpha q(s_{i+1}) + (1-\alpha) I(s_i)$$
$$= q(s_{i+1}) \text{ OVER } I(s_i)$$

The Over Operator



$\mathbf{c}_f = (0,\ 1,\ 0)$
$\alpha_f = 0.4$

front

$$\begin{aligned} \mathbf{c} &= \alpha_f \mathbf{c}_f + (1 - \alpha_f)\alpha_b \mathbf{c}_b \\ \alpha &= \alpha_f + (1 - \alpha_f)\alpha_b \end{aligned}$$

$$\begin{aligned} \mathbf{c} &= 0.4 \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} + (1 - 0.4) \times 0.9 \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} 0.54 \\ 0.4 \\ 0 \end{pmatrix} \\ \alpha &= 0.94 \end{aligned}$$

$\mathbf{c}_b = (1,\ 0,\ 0)$
$\alpha_b = 0.9$

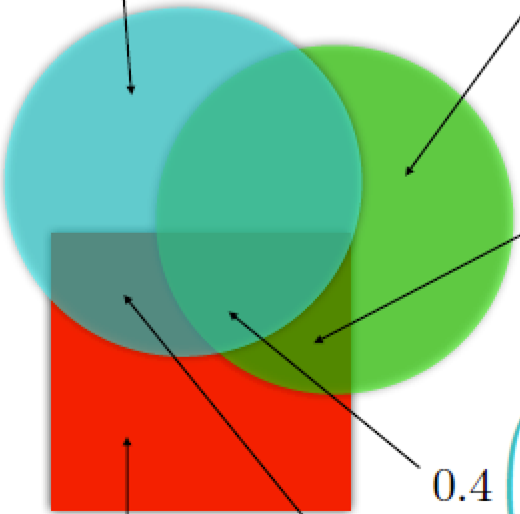
back

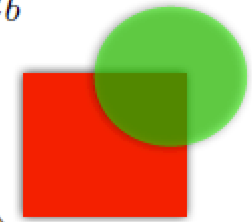
Order of Computation

$\mathbf{c}_f = (0,\ 1,\ 1)$
$\alpha_f = 0.4$

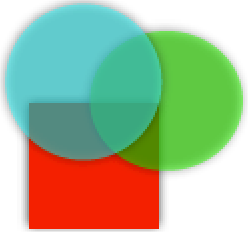
$\mathbf{c}_m = (0,\ 1,\ 0)$
$\alpha_m = 0.4$

$$
\begin{aligned}
\mathbf{c} &= \alpha_f \mathbf{c}_f + (1-\alpha_f)\alpha_b \mathbf{c}_b \\
\alpha &= \alpha_f + (1-\alpha_f)\alpha_b
\end{aligned}
$$





$$0.4\begin{pmatrix}0\\1\\0\end{pmatrix} + (1-0.4)\times 0.9\begin{pmatrix}1\\0\\0\end{pmatrix} = \begin{pmatrix}0.54\\0.4\\0\end{pmatrix}$$



$$0.4\begin{pmatrix}0\\1\\1\end{pmatrix} + (1-0.4)\begin{pmatrix}0.54\\0.4\\0\end{pmatrix} = \begin{pmatrix}0.324\\0.64\\0.4\end{pmatrix}$$

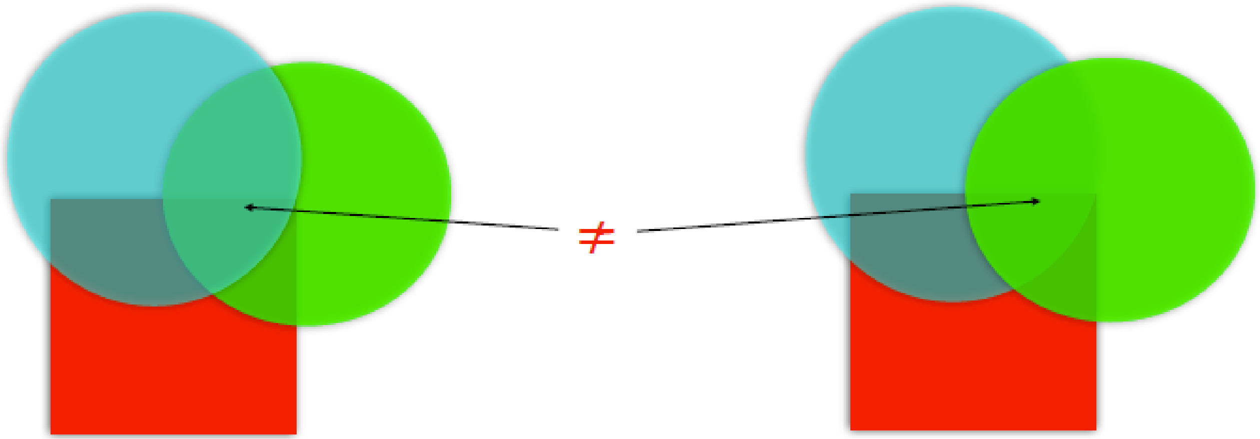
$$0.4\begin{pmatrix}0\\1\\1\end{pmatrix} + (1-0.4)\times 0.9\begin{pmatrix}1\\0\\0\end{pmatrix} = \begin{pmatrix}0.54\\0.4\\0.4\end{pmatrix}$$

$\mathbf{c}_b = (1,\ 0,\ 0)$
$\alpha_b = 0.9$

Order of Computation

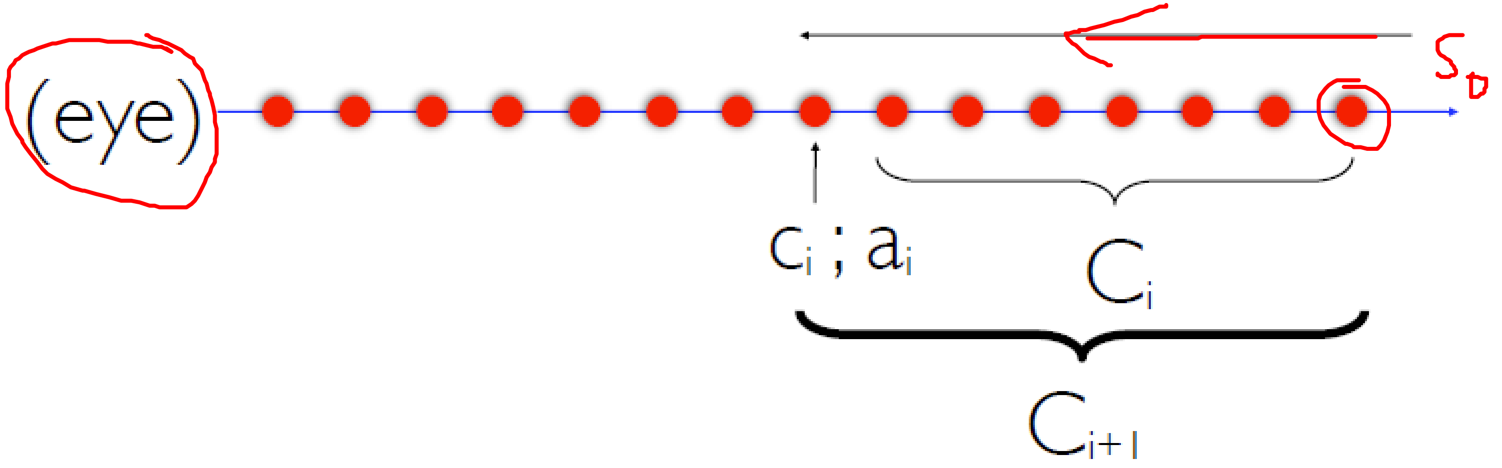
$$
\begin{aligned}
\mathbf{c} &= \alpha_f \mathbf{c}_f &&+ (1-\alpha_f)\alpha_b \mathbf{c}_b \\
\alpha &= \alpha_f &&+ (1-\alpha_f)\alpha_b
\end{aligned}
$$

Order Matters!



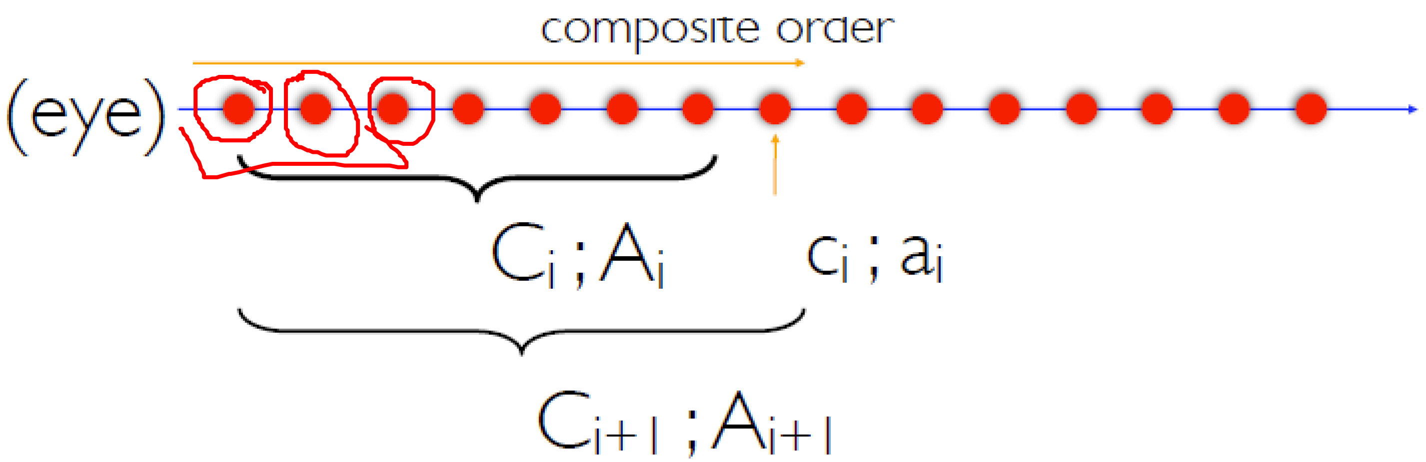
$$
\begin{aligned}
\mathbf{c} &= (0.324,\ 0.64,\ 0.4) \\
\alpha &= 0.964
\end{aligned}
\qquad
\begin{aligned}
\mathbf{c} &= (0.324,\ 0.64,\ 0.24) \\
\alpha &= 0.964
\end{aligned}
$$

Back to Front



$$\boxed{C_{i+1} = a_i c_i + (1-a_i)C_i}$$

Front to Back



$$C_{i+1} = C_i + (1 - A_i)a_i c_i$$
$$A_{i+1} = A_i + (1 - A_i)a_i$$

Order of Composition

Back to Front

straightforward use of over operator

intuitively backwards?

Front to Back

intuitively right?

not simple over operator

facilitates early ray termination

Pre-multiplied Alpha

With pre-multiplied alpha, a color value is given by $\mathrm{c} = (\alpha r, \alpha g, \alpha b, \alpha)$

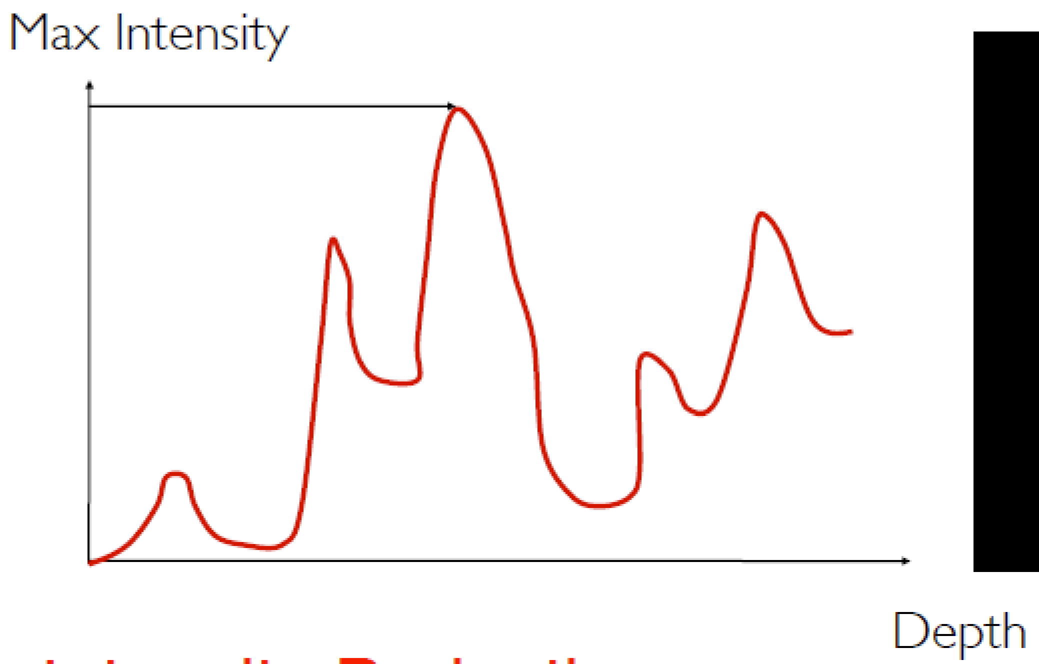
- Sometimes called *associated alpha*
- *Unassociated alpha* = non-pre-multiplied alpha
- **These two versions of alpha will not give the same results for all operations!**

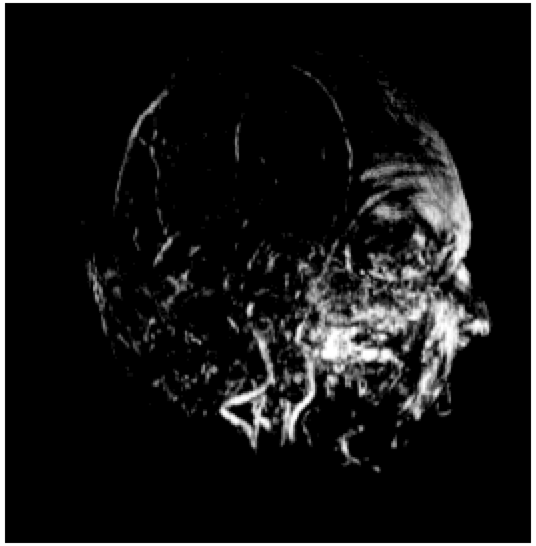
- Can blend using the over operator and pre-multiplied alpha

$$\mathbf{c}_o = \mathbf{c}'_s + (1 - \alpha_s)\mathbf{c}_d$$

- Here $\mathrm{c}' = (\alpha r, \alpha g, \alpha b)$
- Again, c_d is assumed to be opaque

Alternative to Compositing: Maximum Intensity Projection





Maximum Intensity Projection
Magnetic Resonance Angiogram

$$I(p) = f(\max(s(t)))$$

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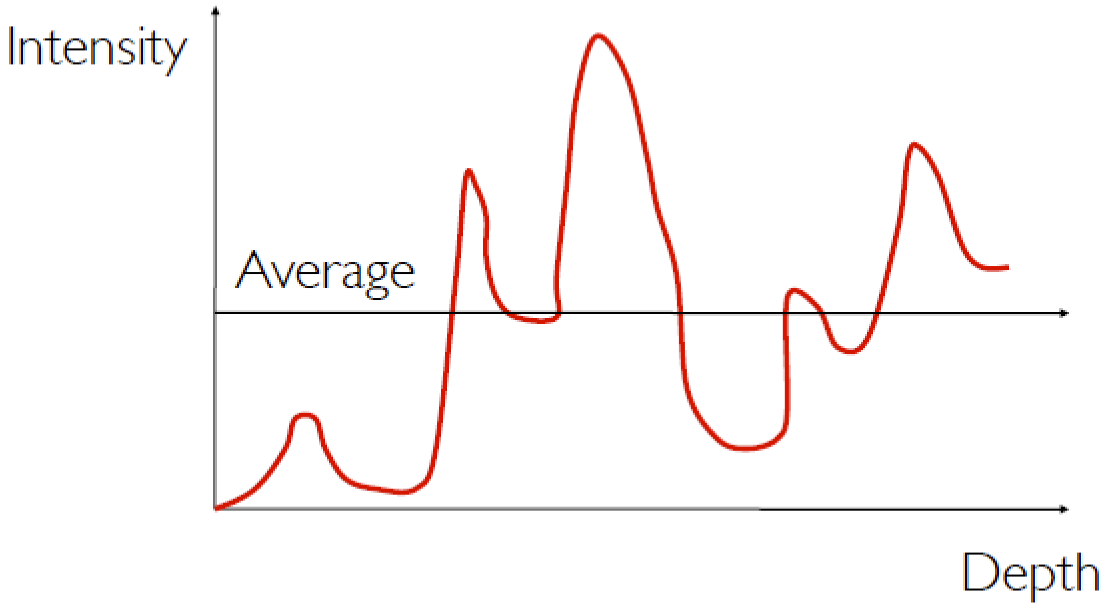
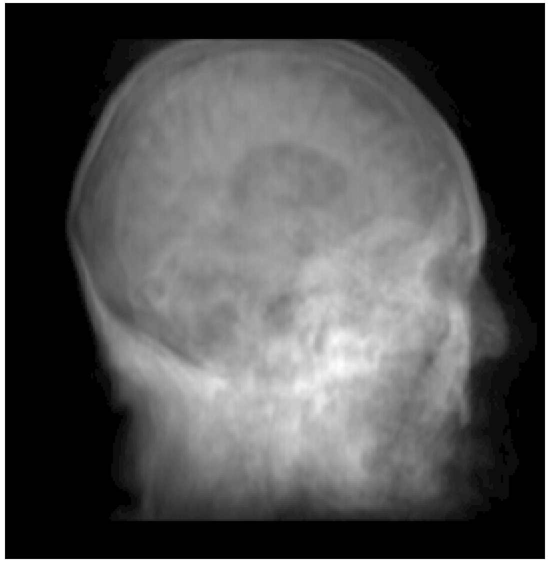
Alternative to Compositing: Average Intensity Projection





$$I(p) = f\left(\frac{\int_{t=0}^{T} s(t)dt}{T}\right)$$

Analogous to an x-ray

Synthetic Reprojection