Volumetric Image Visualization

Alexandre Xavier Falcão

LIDS - Institute of Computing - UNICAMP

afalcao@ic.unicamp.br

Introduction

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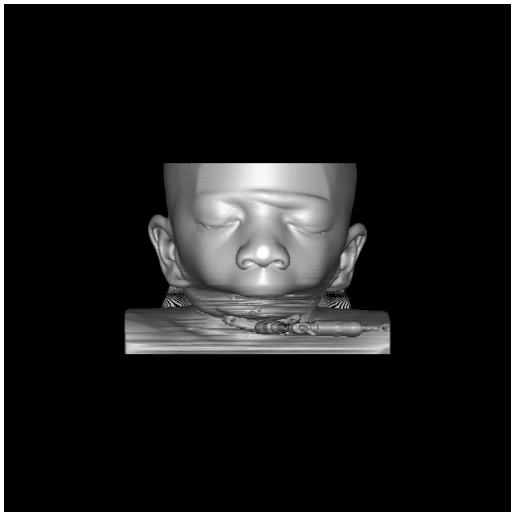
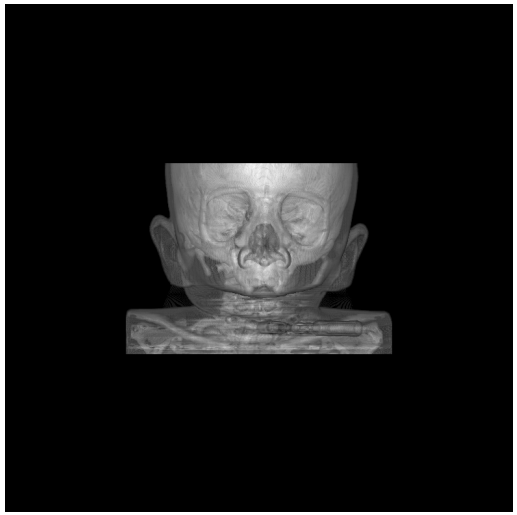
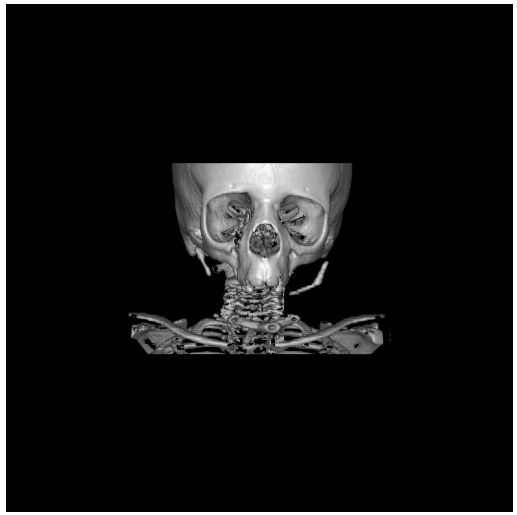
- The method, called volume rendering, is limited but useful in some situations.
- This lecture covers the volume rendering algorithm, its advantages and limitations.

Transfer functions

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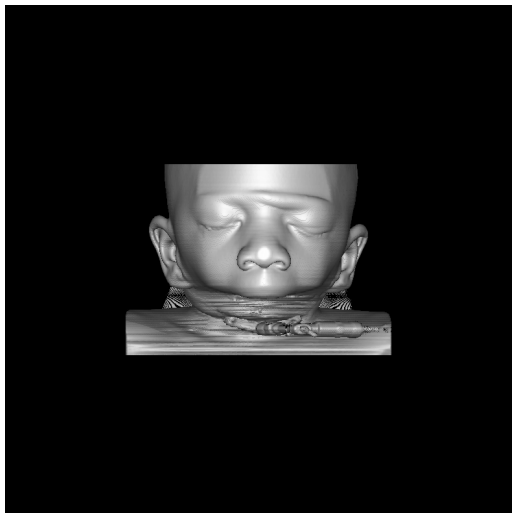
$$\begin{aligned} \alpha(p) &= \begin{cases} \alpha_{\max}(1.0 - \frac{G(p)-T_g}{G_{\max}-T_g}) & \text{if } G(p) \geq T_g \text{ and} \\ & T_l \leq I(p) \leq T_h, \\ 0 & \text{otherwise,} \end{cases} \\ G_{\max} &= \max_{\forall p \in D_I} \{G(p)\}, \end{aligned}$$

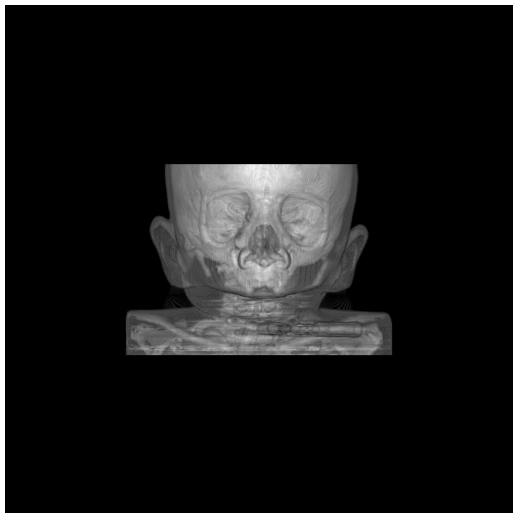
where $\alpha_{\max}$ is the maximum opacity assigned to a spel, T_g is 90% of the Otsu's threshold on G, T_l and T_h are given intensity thresholds.

Transfer functions

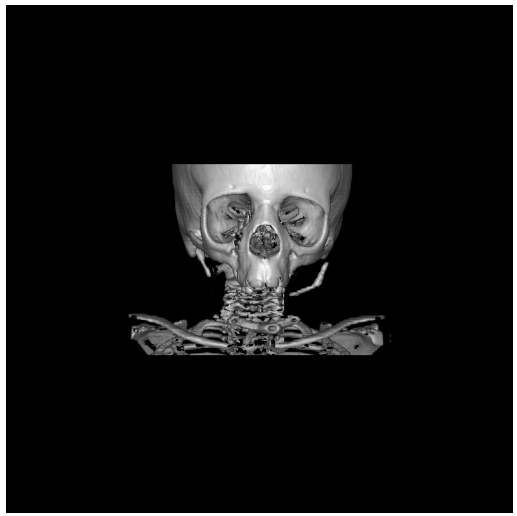
A transfer function should enhance the boundary between distinct tissues (regions).



(a)



(b)



(c)

(a) $\alpha_{max} = 1.0,\ T_l = 20,$ and $T_h = 255.$

(b) $\alpha_{max} = 0.1,\ T_l = 20,$ and $T_h = 255.$

(c) $\alpha_{max} = 1.0,\ T_l = 80,$ and $T_h = 255.$

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- A pattern classifier could be trained to assign opacity values based on texture gradients.
- Some formulations also adopt the Hessian matrix (second derivatives).
- In any case, a transfer function aims to substitute image segmentation into multiple objects.

Advantages and limitations

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- Transfer functions are simple and effective in some situations.
- All voxels with some opacity value are candidates for visualization, which may slow down the rendering.
- The absence of object information makes impossible to create normal vectors pointing to the exterior of the objects.
- The only approach for normal estimation is the scene-based method, which it is not suitable in some cases (e.g., bones in MR).

Volume rendering algorithm

Input : Graphical context gc, and viewing angles α and β.
Output: Rendition $\hat{J} = (D_J, J)$.

1 $\mathbf{n}' \leftarrow \phi_r^{-1}(\mathbf{n})$, where $\mathbf{n} = (0, 0, 1, 0)$.
2 For each $p \in D_J$ do
3 $\quad p_0 \leftarrow \phi^{-1}(p)$.
4 $\quad$ Find $\mathcal{P} = \{p_1, p_n\}$ by solving $\langle p_0 + \lambda \mathbf{n}' - f.c, f.\mathbf{n} \rangle = 0$ for each face $f \in \mathcal{F}$ of the scene, whenever they exist.
5 $\quad$ if $\mathcal{P} \neq \emptyset$ then
6 $\quad\quad J(p) \leftarrow$ ComputeShadingAlongRay$(gc, \mathcal{P})$.

Shading along a viewing ray

1 If $p_1 = p_n$ then set $n \leftarrow 1$.
2 Else
3 Set $D_x \leftarrow x_{p_n} - x_{p_1}$, $D_y \leftarrow y_{p_n} - y_{p_1}$, $D_z \leftarrow z_{p_n} - z_{p_1}$.
4 If $|D_x| \geq |D_y|$ and $|D_x| \geq |D_z|$ then
5 Set $n \leftarrow |D_x| + 1$, $d_x \leftarrow sign(D_x)$, $d_y \leftarrow \frac{d_x D_y}{D_x}$, and $d_z \leftarrow \frac{d_x D_z}{D_x}$.
6 Else
7 If $|D_y| \geq |D_x|$ and $|D_y| \geq |D_z|$ then
8 Set $n \leftarrow |D_y| + 1$, $d_y \leftarrow sign(D_y)$, $d_x \leftarrow \frac{d_y D_x}{D_y}$, and $d_z \leftarrow \frac{d_y D_z}{D_y}$.
9 Else
10 Set $n \leftarrow |D_z| + 1$, $d_z \leftarrow sign(D_z)$, $d_x \leftarrow \frac{d_z D_x}{D_z}$, and $d_y \leftarrow \frac{d_z D_y}{D_z}$.

Shading along a viewing ray

11 Set $k \leftarrow 1$ and $t \leftarrow 1.0$.
$p' \leftarrow (x_{p_1}, y_{p_1}, z_{p_1})$, and $r_t \leftarrow 0$.
12 While $k \leq n$ and $t > \epsilon$, do
13 Set $p' \leftarrow (\lceil x_{p'} \rceil, \lceil y_{p'} \rceil, \lceil z_{p'} \rceil)$.
14 If $\alpha(p') > 0$ then
15 $r_t \leftarrow r_t + t \times \alpha(p') \times r(p')$.
16 $t \leftarrow t \times (1 - \alpha(p'))$.
17 Set $p' \leftarrow (x_{p'}, y_{p'}, z_{p'}) + (d_x, d_y, d_z)$
18 return r_t.

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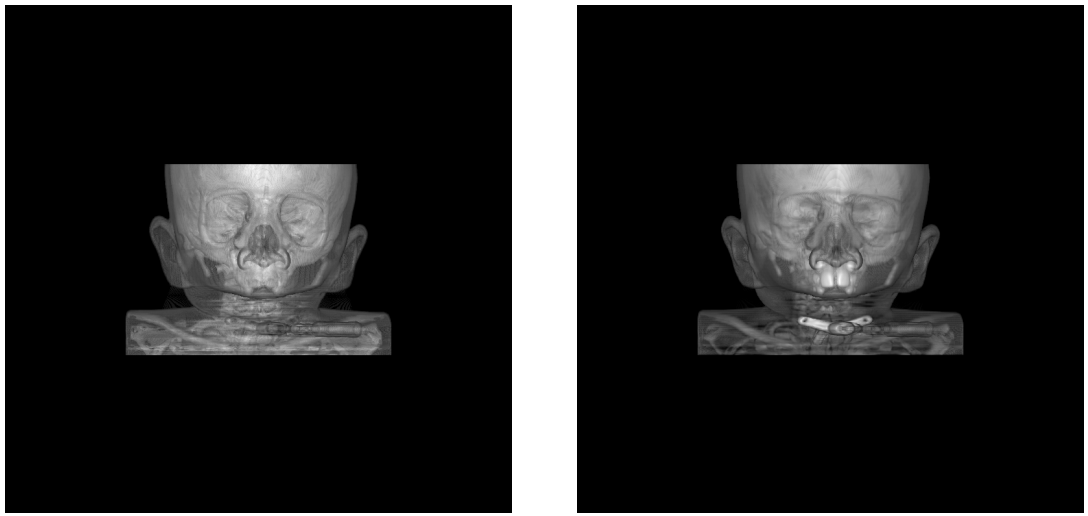
17 Set $p' \leftarrow (x_{p'}, y_{p'}, z_{p'}) + (d_x, d_y, d_z)$
18 return r_t.

It is better to use p' with real coordinates in Lines 15-16, with normal and opacities estimated by interpolation.

Examples

A small change in the transfer function makes impossible to view only skin or skull.

$$\alpha(p) = \begin{cases} \alpha_{\max}\frac{G(p)-T_g}{G_{\max}-T_g}) & \text{if } G(p) \geq T_g \text{ and} \\ & T_l \leq I(p) \leq T_h, \\ 0 & \text{otherwise,} \end{cases}$$

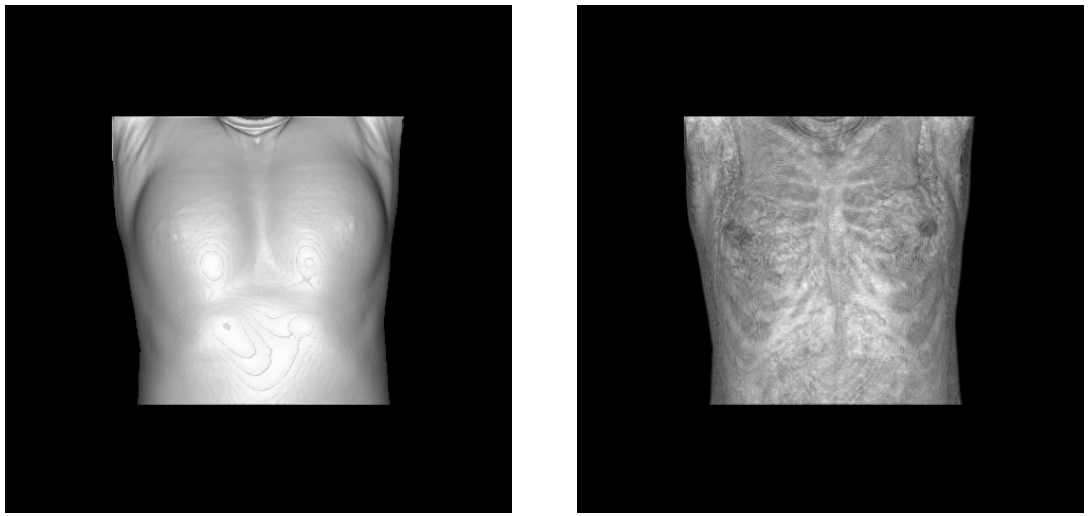


(a) (b)

(a) The previous formula with $\alpha_{\max} = 0.1$.
(b) The formula above with $\alpha_{\max} = 1.0$.

Examples

Volume rendering of the thorax.



(a) (b)

(a) $\alpha_{max} = 1$, $T_g = 400$, $T_l = 2400$, and $T_h = 4095$.

(b) $\alpha_{max} = 0.1$, $T_g = 400$, $T_l = 2400$, and $T_h = 4095$.