Medical Imaging

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Color Mapping

Color Mapping

- Tomographic image $I(x, y)$ carries real valued information (e.g. 3.9343)
- How to display it on the computer screen

$\Rightarrow$ Map real value to color

Color Mapping

Gray colormap
A gray color c is usually represented in number form as an element of $[0, 1]$ where 0 is the color **black** and 1 is the color **white**. In-between all shades of gray are defined.

General colormap
A general color c is usually represented as an RGB tuple $c = (r, g, b) \in [0, 1]^3$. A **colormap** $f : [0, 1] \to [0, 1]^3$ maps an input value between 0 and 1 to an output color.

Color Mapping

Remark

The colormap is defined on the domain of real numbers in the interval $[0, 1]$. In practice colormaps are build using a set of discrete colors. Using linear interpolation it is possible to define a continuous function based on the discrete values.

Example

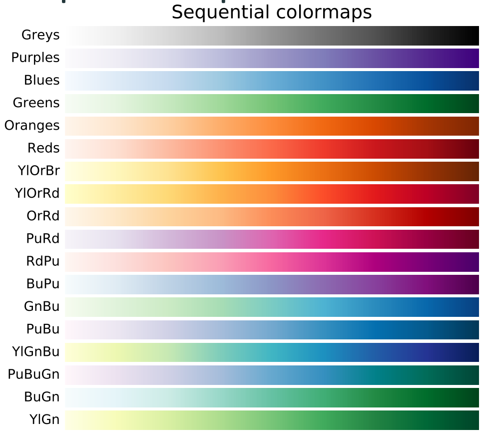
Let $c_k \in [0, 1]^3$ for $k = 1, \ldots, K$ be K colors. Then we can define

$$f(\alpha) = \begin{cases} c_\beta & \text{if } \beta \text{ is an integer} \\ (1 - w)c_{\lfloor \beta \rfloor} + wc_{\lfloor \beta \rfloor + 1} & \text{otherwise} \end{cases}$$

to be the linearly interpolated colormap with $\beta = \alpha(K - 1) + 1$, which is α scaled to $[1, K]$, and weighting $w = \beta - \lfloor \beta \rfloor$.

Color Mapping

Example Colormaps



Color Mapping

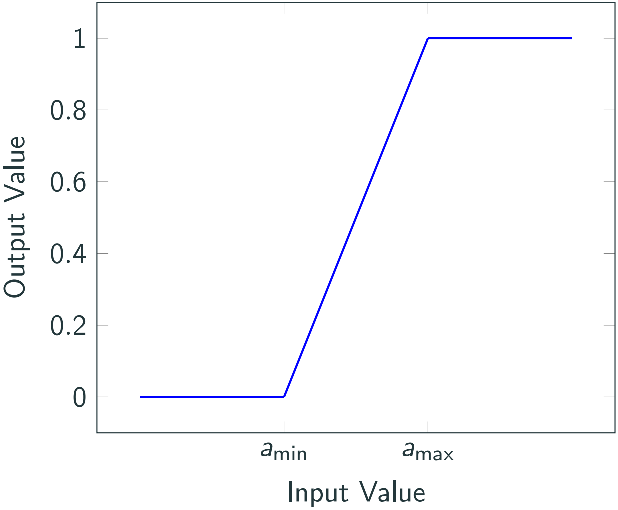
Ingredients

- a colormap $f(\alpha)$
- a minimal value a_{min} that maps to the darkest color $f(0)$
- a maximal value a_{max} that maps to the brightest color $f(1)$

Windowing
The mapping between real valued quantity I and the color c is called **windowing** and can be expressed by a function

$$g(a) = \begin{cases} 0, & \text{for } a \leq a_{\text{min}} \\ \frac{a - a_{\text{min}}}{a_{\text{max}} - a_{\text{min}}}, & \text{for } a_{\text{min}} < a < a_{\text{max}} \\ 1, & \text{for } a \geq a_{\text{max}} \end{cases} \tag{1}$$

Color Mapping



Color Mapping

Algorithm
For each image pixel at position x, y calculate:

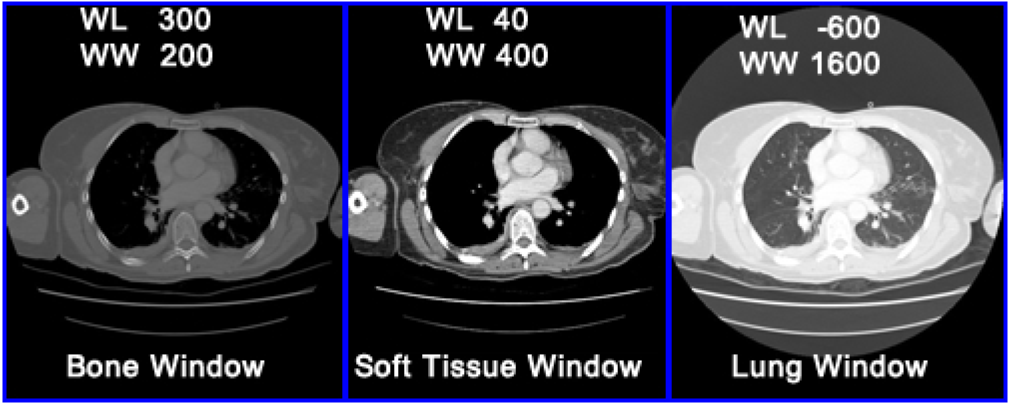
$$I_{\text{colorized}}(x, y) = f(g(I(x, y)))$$

Instead of a_{min} and a_{max} it is common to consider instead

$$\text{WW} = a_{\text{max}} - a_{\text{min}} \quad \text{(Window Width or Contrast)}$$
$$\text{WL} = \frac{a_{\text{max}} + a_{\text{min}}}{2} \quad \text{(Window Level or Brightness)}$$

Remark
The human eye can only differentiate a certain number of gray values. It is very common that WW does not span the entire range of image values ($[\min\{I\}, \max\{I\}]$) but WW and WL are adapted to a certain range that the radiologist wants to differentiate. In usual applications there are usually sliders for adjusting WW and WL.

Color Mapping



CT Windows

In CT there one has defined dedicated windows for specific applications

	WL	WW
lung window	-600	1600
bone window	300	2000
soft tissue window	60	360
brain window	40	80
CT angiography window	100	900

Lung CT Example Dataset

- To play around with image contrast parameters you can download the file `lung.tif.zip` from Stud.IP and unzip it.
- Then download the software ImageJ (`https://imagej.nih.gov/ij/`) or use the web-based instance of ImageJ (Run ImageJ in the Browser!)
- Open the TIF image (or the unzipped TIF) in ImageJ and open the menu *Image / Adjust / Window/Level*
- Play around with WW and WL and try to select different parts of the thorax slice (e.g. the lungs, soft tissue, bones).