How to use the transfer function editor in CTVox

Method note

MCT-102

Innovation with Integrity

microCT

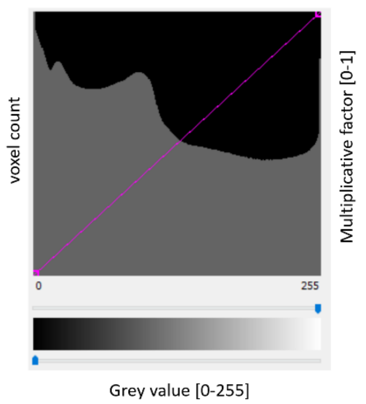
CTVox is an easy-to-use volume rendering package that allows to create realistic 3D images and movies of your microCT data. A Quickstart guide that will help you get started with this intuitive software can be found on our website. More tips and tricks on how to easily generate appealing images and movies can be found in method note MN87 “tips and tricks for your images and movies”. This method note will focus in more detail on the transfer function editor, which CTVox offers for fast and flexible creation of images with vivid and revealing color and texture.

Note that as from version 3.3 RGB markers can be created intuitively, demonstrated in MN103: “New in CTVox 3.3”.

How does the transfer function editor work?

Every voxel in the volume dataset has a grey value. In volume rendering, every voxel in the dataset is assigned an emission color as well as an opacity (the opposite of transparency).

The transfer function allows to map grey values with these parameters through different components or channels. These 4 channels are R (red), G (green), B (blue), and opacity. Note if the color channels are linked, only 2 channels are available: L (luminescence or intensity) and opacity. The transfer function editor can be found on the left side of the CTVox window. The horizontal axis in the plot represents the original dataset grey values (the x-ray attenuation), the vertical axis represents one of the transfer function components (R, G, B, Opacity). On the same window the histogram is shown. The resulting final appearance of each voxel is a combination of each component and the result can be seen in the color bar below the transfer function editor, indicated with a blue arrow.

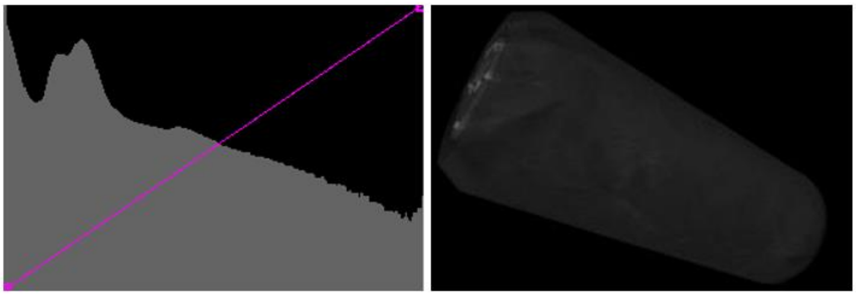


1. Opacity

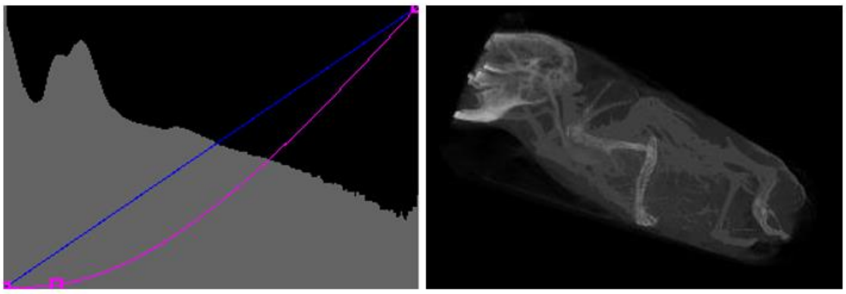
The opacity channel controls the visibility of the corresponding voxels/materials. By setting the opacity for a given grey value range to zero, the material is made fully transparent, the corresponding voxels are effectively made invisible.

The steps below (also documented in our CTVox Quickstart guide, downloadable from our website) give a nice step-by-step example how to modify the opacity channel:

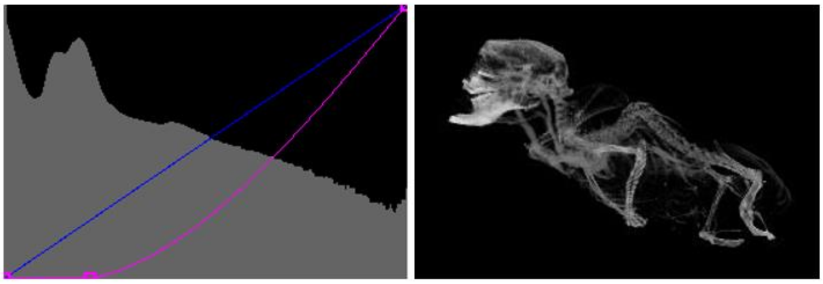
- Make the opacity channel active in the transfer function editor, by selecting opacity from the channel drop down box. The markers for the purple opacity curve (initially a straight line, with just two markers, one at each end) appear, to indicate it is active. Opacity of the opposite of transparency. Hence, we will need to map low intensities to low opacities (= high transparency)



- Add a marker to the opacity curve by clocking in the lower left corner of the transfer function window: the curve changes to smoothly pass through the new and existing markers.

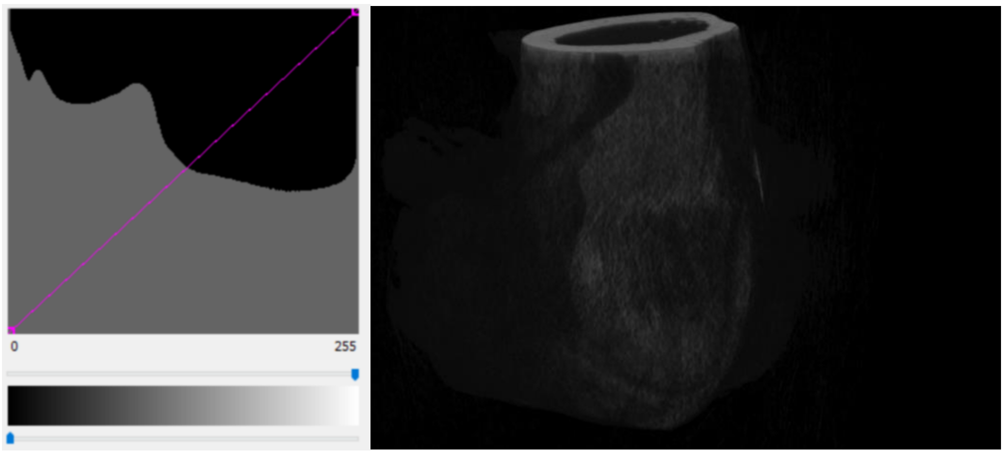


- Try moving the marker to smoothly change the transfer function and obtain the desired effect: left click the marker and drag the mouse with the left mouse button held down. One can switch between a spline (smooth) curve and a polygonal line by toggling Use splines in the context menu (invokes by right-clicking in the transfer function plot area). The context menu also includes entries to reset the currently active or all curves and to delete a marker (when invoked with the mouse pointer over a marker). Markers can also be deleted by double clicking them.

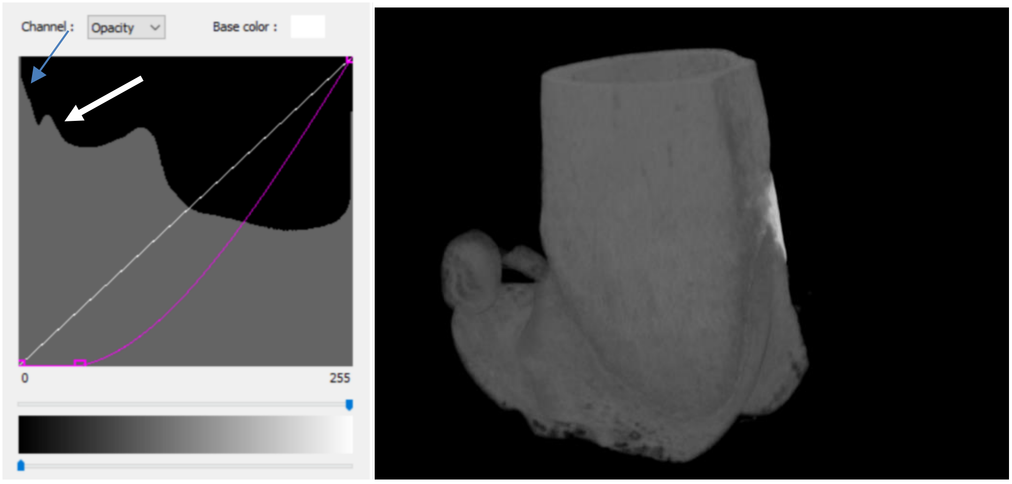


The next example shows a bone with a titanium implant volume rendered.

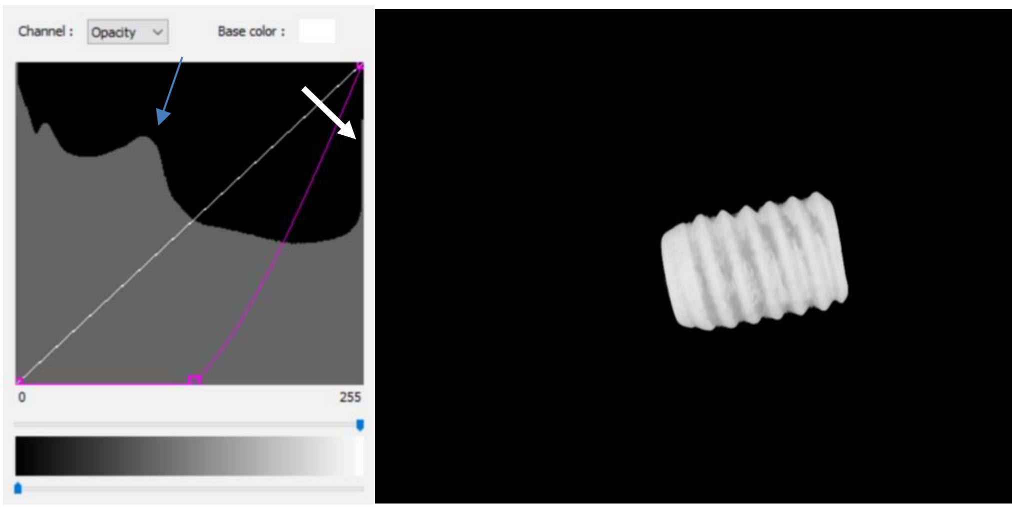
- The top image shows the default setting for transfer function (left) and corresponding volume rendered image (right).



- Next, the transfer function has been modified to suppress these lowest densities, corresponding with air and background noise (indicated with a thin blue arrow) and soft tissue (thick white arrow)

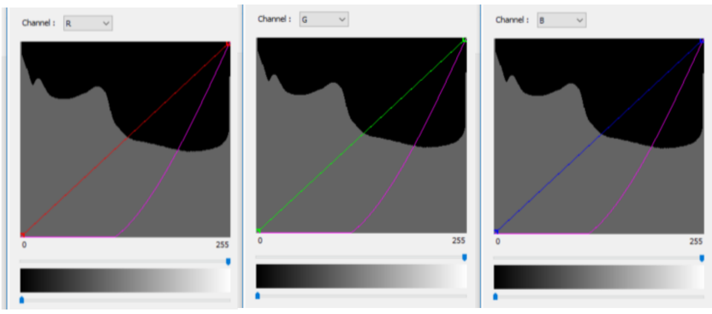


- In the next image, the densities representing the bone material (indicated with a thin blue arrow) are made transparent, leaving only the high dense titanium voxels (thick white arrow) visible in the volume rendered image. A good understanding and interpretation of the image histogram is crucial in fluently modifying the transfer function editor.

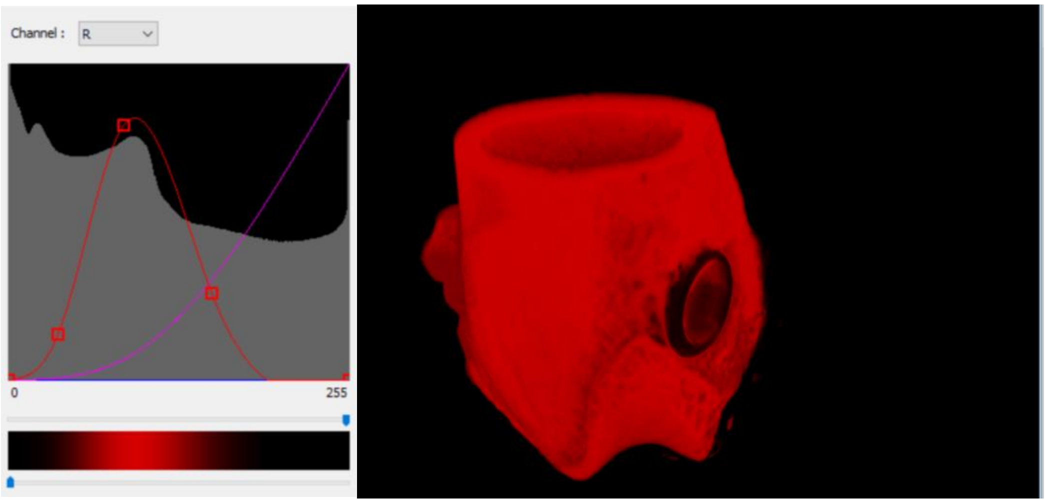


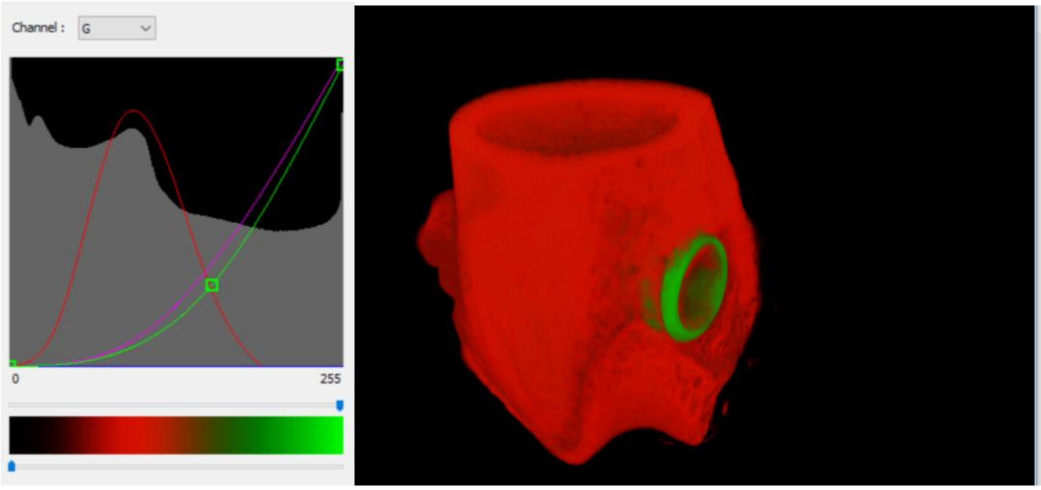
2. Colour

In the previous example(s) only the opacity was modified. The color bar remains the same in all situations. We will now switch the active channel to any of the color channels R, G, B. The default settings for each channel are as shown below.

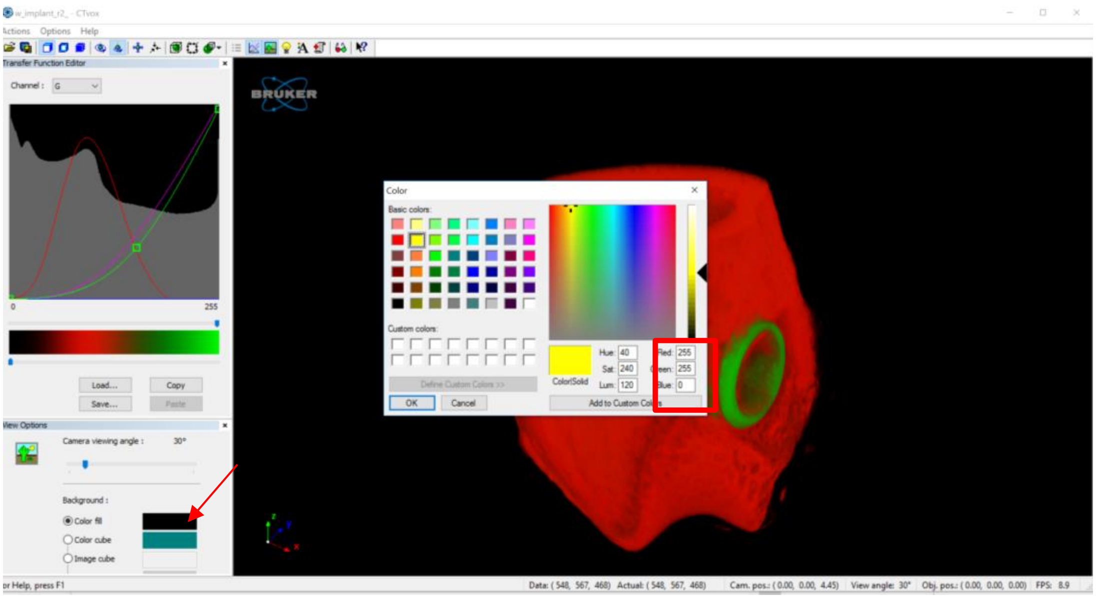


Different colors can be applied to different materials by fine tuning the different channels. Easiest is to put all three channels to black before you get started. Then add weight to the desired channel in the intensity range. In our example, we identified the intensity range for the bone material, and increased the R signal, secondly the intensity range for titanium was identified at the left of the image histogram and the G signal was applied in this region. For each step it is shown how it affects the resulting color bar and volume rendered image.

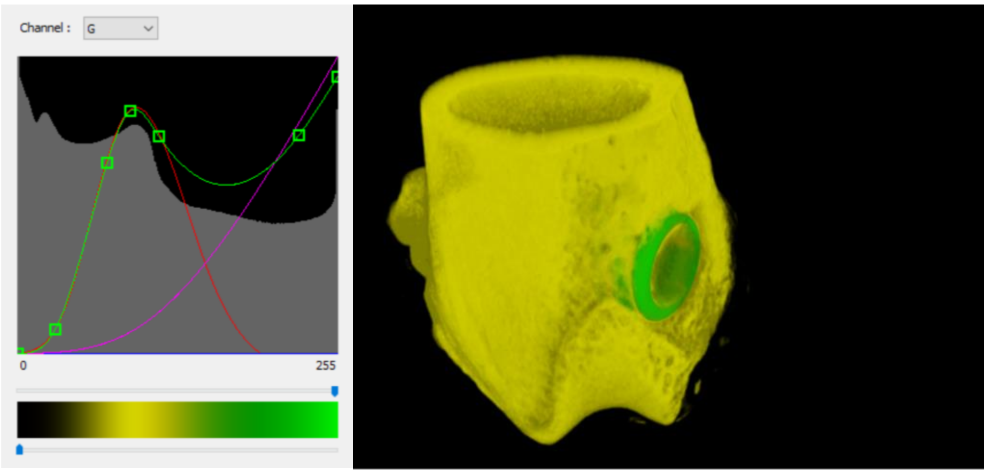




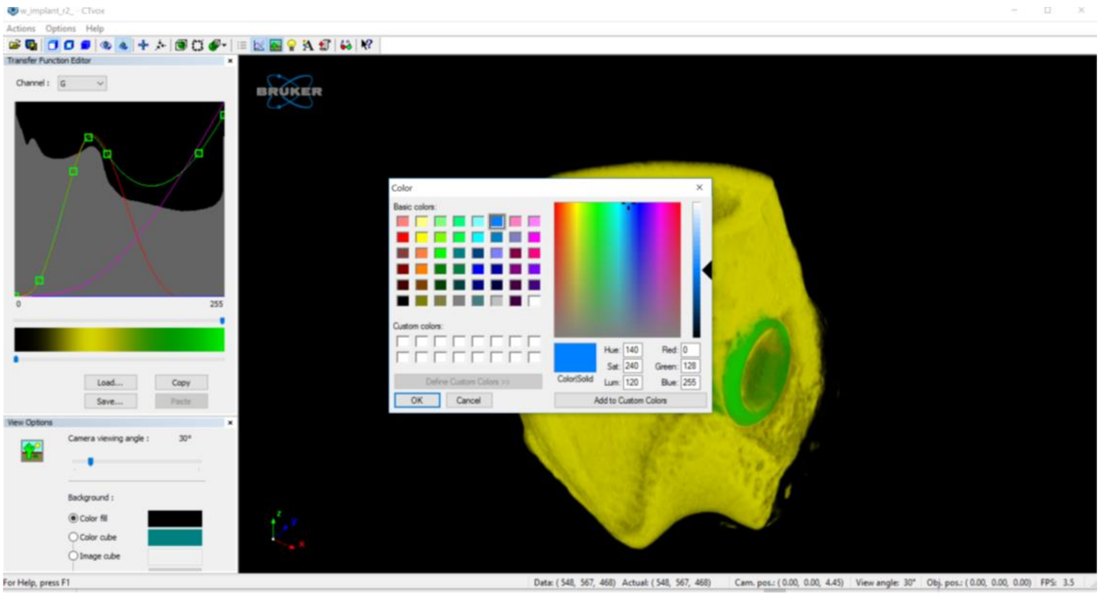
Any color can be created by combining red, green and blue in different ratios. At some point in life, everybody has once mixed red and blue paint to find a purple color. CTVox applies the same concept of mixing different ratios of the 3 base colors, by fine tuning the individual channels. Any desired color can be chosen as a combination of red, green and blue. Black is represented by (0,0,0), white by (255, 255, 255). An easy trick exists to find RGB ratios for any other color. Left clicking in the color box next to ‘color fill’ opens a color window. Any color can be selected here, and the values for RGB to create that specific color can be read in this window. On a scale of 0-255, the yellow color is made of 100% red, 100% green and 0% blue.



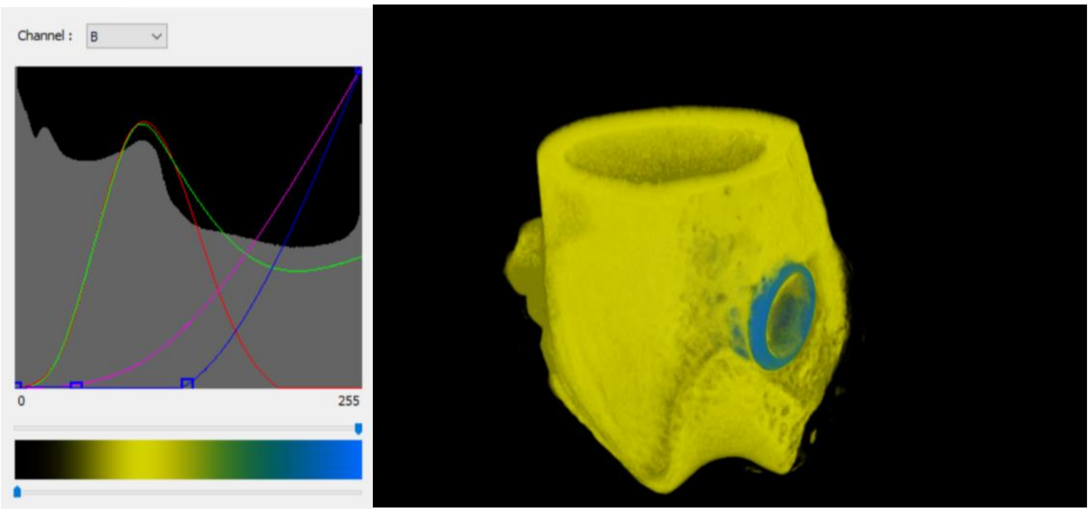
The yellow color can now be introduced into the volume rendered image by modifying the RGB channels individually. When red and green are in equal amounts, the bone shows a yellow color.



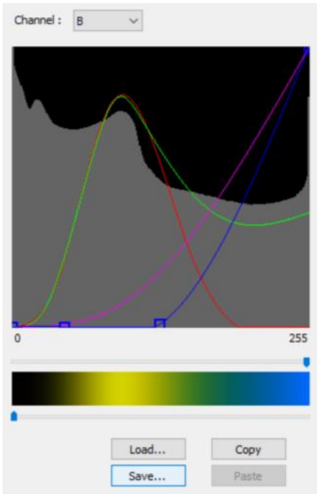
The color code for the blue shade in the example below is (0, 128, 255), which means no red, 50% of green and 100% of blue.



The blueish color will now be used for the implant by adjusting the G and B channel accordingly.



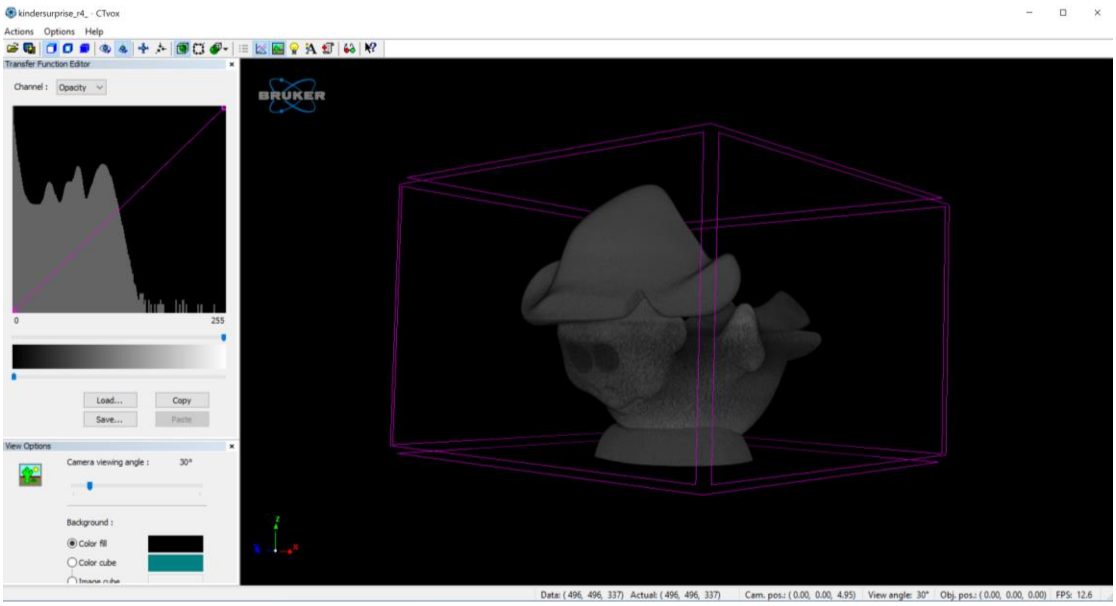
When the resulting color bar is satisfactory, it is possible to save this transfer function, and load it back at a later point in time for the same data or to reapply it to a similar sample.



Exercise

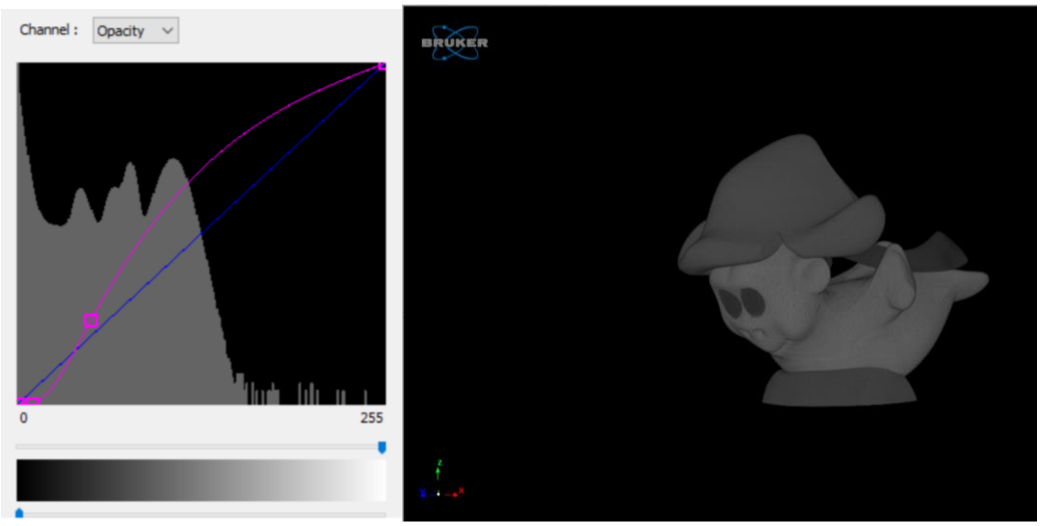
On our sharepoint you can find the small and easily usable dataset 'kindersurprise' to download for this exercise. This old dataset has been used to train hundreds of users throughout the years because its easily recognizable and its nice image histograms. By zooming out (scrolling) and rotating the sample it can be seen that the volume is a toy in the shape of a small puppet. The kindersurprise toy consist of 3 well differentiated types of plastic, used for the eyes, hat and body respectively. These plastics represent three distinct peaks in the image histogram. The goal of this exercise is to assign specific colors:

- Exercise A : eyes - red, hat - green, body - blue
- Exercise B : eyes - red, hat - yellow, body - blue

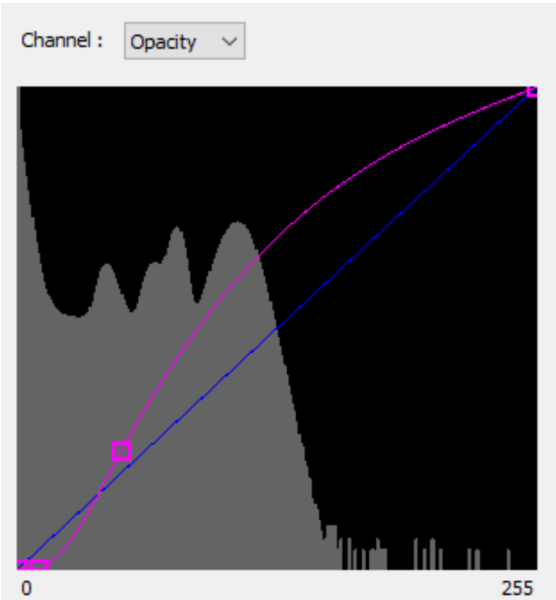


Solution Exercise A : eyes - red, hat - green, body – blue

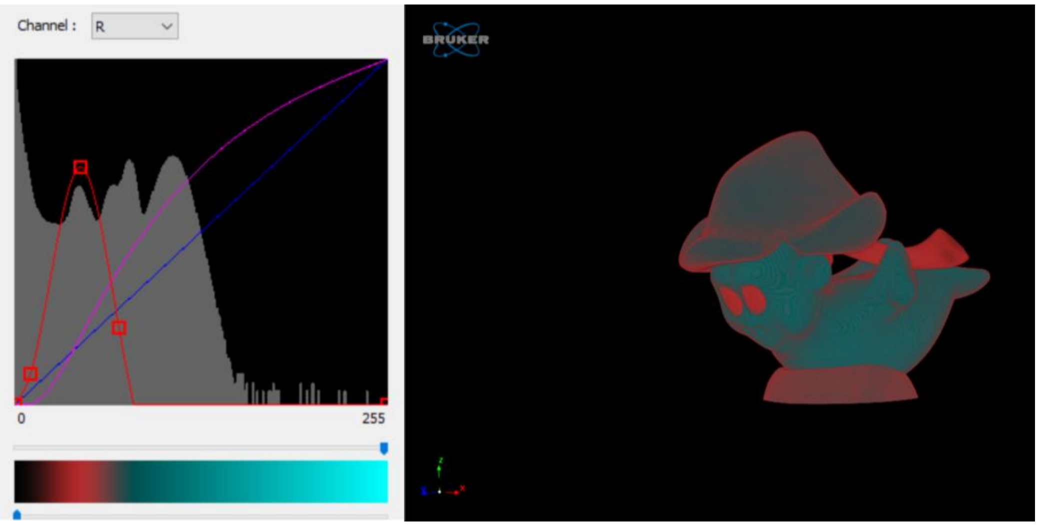
Firstly, suppress the noise which is low dense, by minimizing the opacity channel on the left side of the editor window.



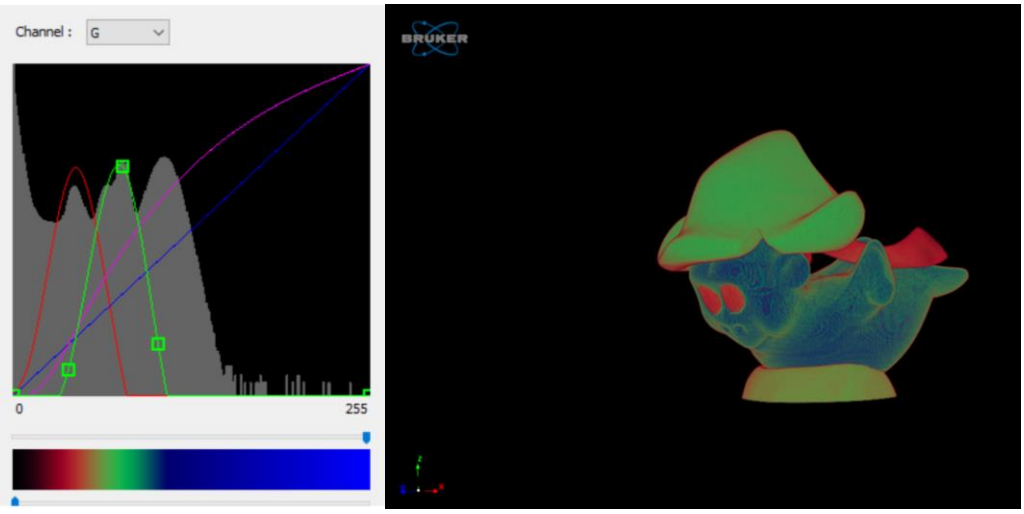
Now, identify the eyes, hat and body in the histogram.



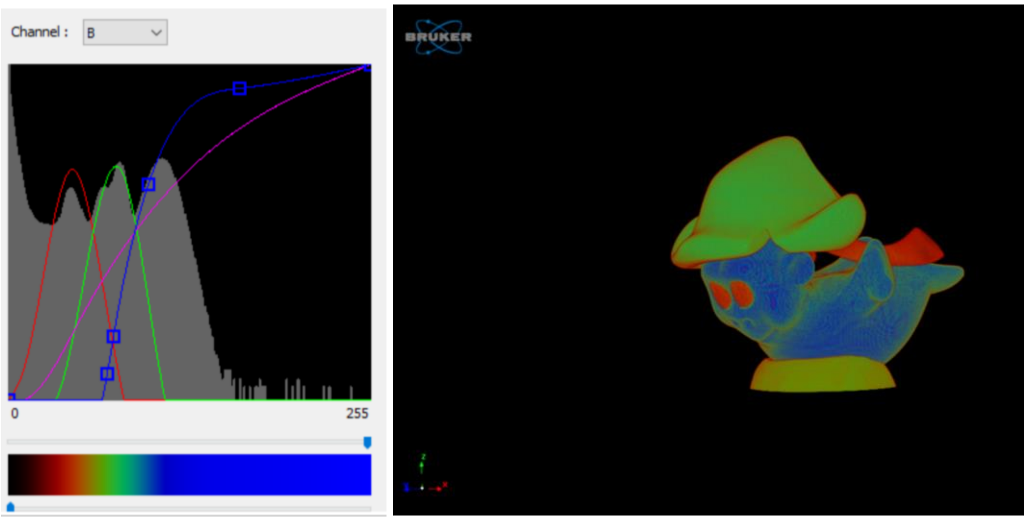
Now switch to the red channel to apply red to the eyes.



Now switch to the green channel to apply a green color to the hat.

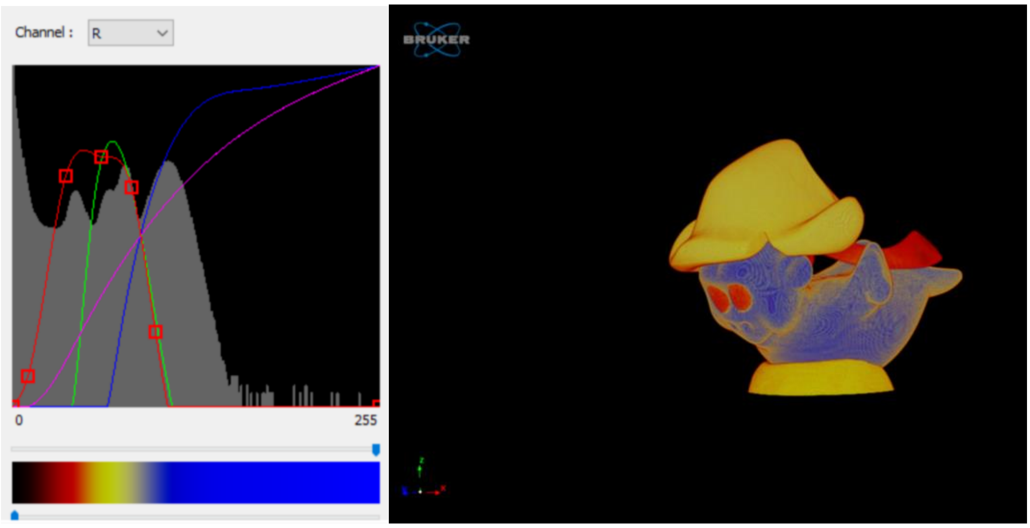


And finally switch to the blue channel to apply blue color to the body.



Solution Exercise B : eyes - red, hat - yellow, body – blue

The only thing that needs to be modified is the color of the hat, which is the middle peak. Yellow is a combination of red and green. Green is already present, hence only the red channel needs to be modified, to equal amounts of red and green. It might be that the green curve needs to be fine-tuned a little.

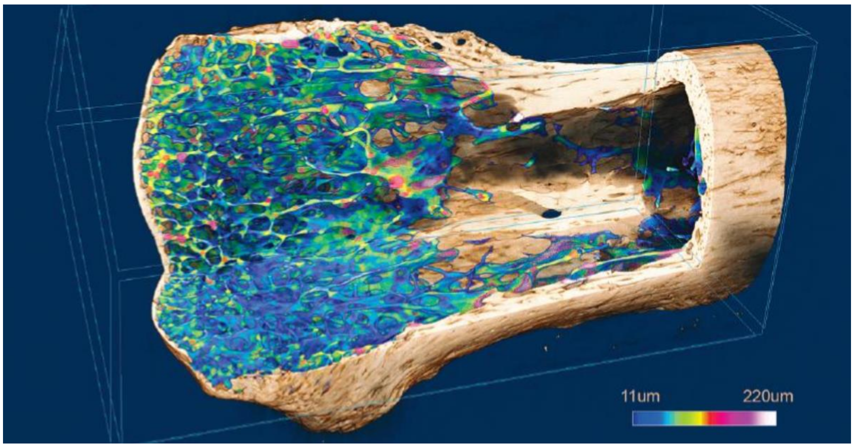


The blue body is surrounded with an orange layer. This is due to the partial volume effect. Because the transition of densities shows a sigmoidal profile, approximately 5-7 pixels are needed for an object to reach its true intensity. Meaning that objects of high density have an outer edge of a few pixels of medium and low density.

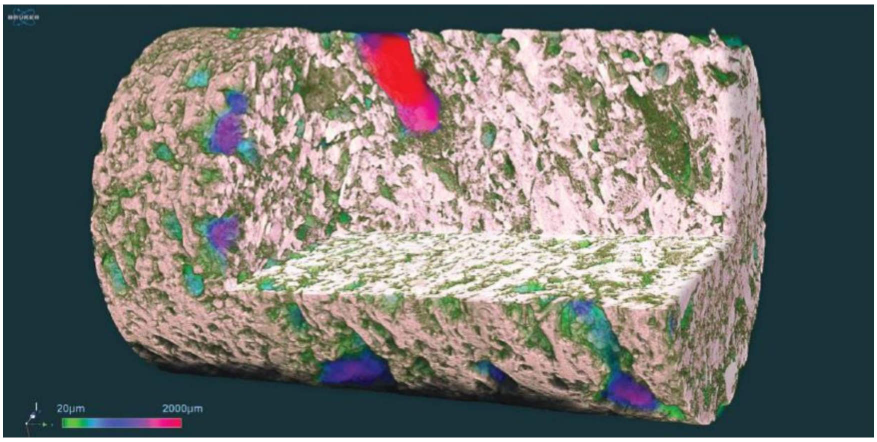
Visualisation of 3D analysis results

Combining the power of 3D numerical analysis of micromorphology in CTAn with the imaging capability of CTVox allows visualizing the 3D distribution of morphological parameters across the scanned volume.

Calculation of local 3D numerical parameters such as structural thickness or separation in CTAn is based on the placing of a spherical probe in every point of the object's 3D spade with maximum diameter which fills structural features. The obtained local information on 3D structural thickness and structural separation can be saved as a spatial intensity map. CTVox converts such maps of measured morphological parameters to color coded 3D images, which reflect local distribution of numerical characteristics of the object. The possibility to work with multiple datasets in CTVox helps to display several parameters simultaneously. For example, using the technique explained above, local structure thickness and separation (pore size distribution) can be coded in complementary color schemes and displayed simultaneously. All such 3D visualizations can be explored by virtual cut and creating fly-through movies as well as all other features of CTVox. Dedicated method notes are available in our online Academy platform. The concept is explained in MN025 "how to make color-coded 3D models for structure thickness using CTVox" and applied in MN090, 091 and 92 on the quantification of adipose tissue in a specific region or whole body of a mouse or rat, MN096 on lung analysis, …



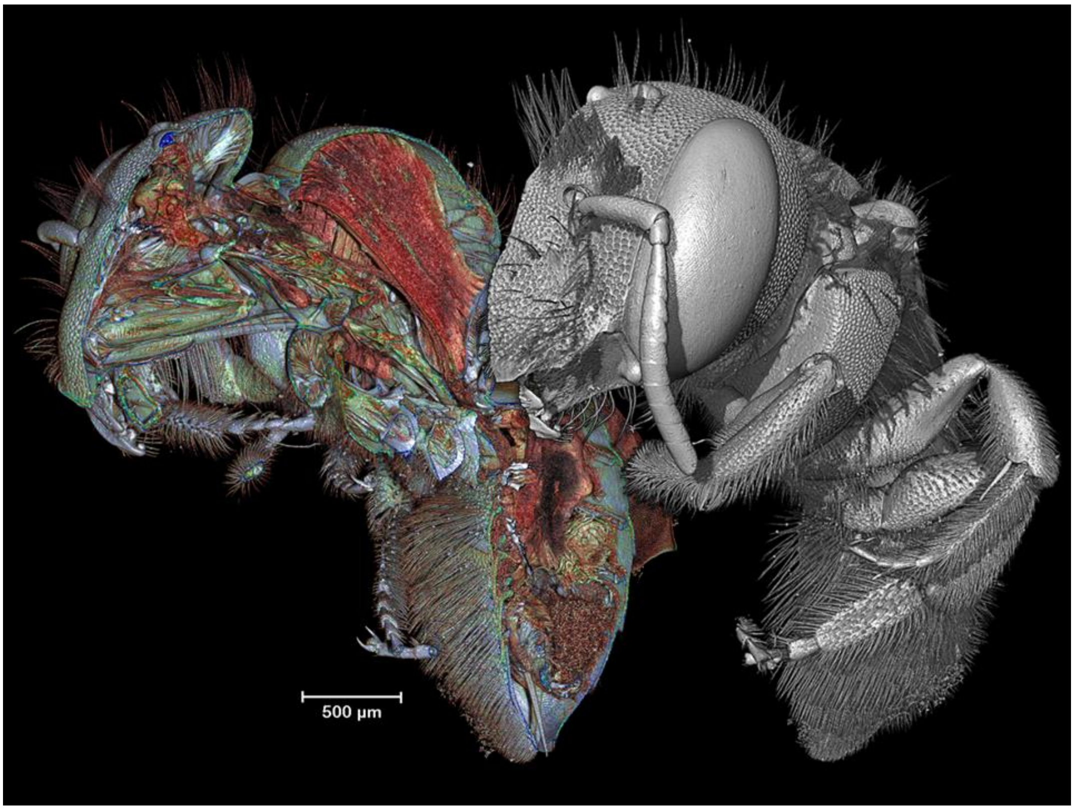
Volume rendering of the structure inside a bone. The left top corner is virtually removed. Color coding of local trabecular thickness. 11 um isotropic resolution, 1944 x 1944 x 2637 pixels.



Volume rendering of the internal structure in a carbonate. The front right corner is virtually removed. Color coding of local pore sizes. 20 um isotropic resolution, 1944 x 1944 x 2925 pixels.

Realistic images

When becoming experienced, it is possible to generate more complex functions for a more realistic and vivid color experience. Below you can find some impressive examples created by our user community.



Dissecting a Masson Bee, J. Alba-Tercedor, University of Granada, micro-CT User meeting 2016

Mouse lung, by Annapaola Parrilli, micro-CT User meeting 2016