Lab Class Visualization

Part 1: Assignments InfoVis: *10 Pt.*
(Patrick Riehmann)

Part 2: Assignments SciVis: *10 Pt.*
(Carl-Feofan Matthes)

Part 3: Final Project: *30 Pt.*

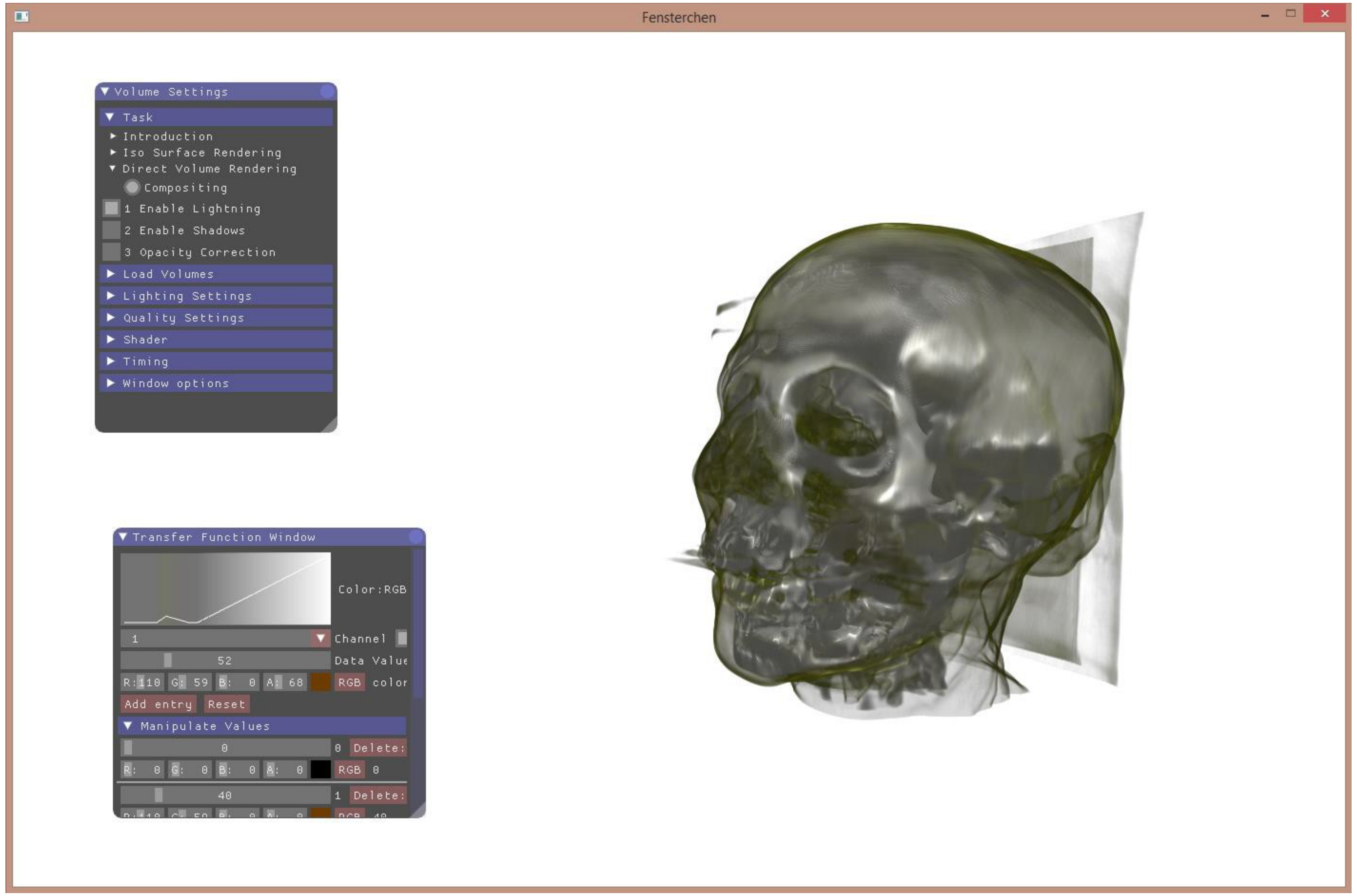
Final Project (SciVis / InfoVis)

- Topic: up to you (either InfoVis or SciVis)
- Expenditure of time: ~40h/Student
- Final Project Submission:
  Short description + source code
  Final project deadline: **Early September**

  Send to
  patrick.riehmann[at]uni-weimar.de
  carl-feofan.matthes[at]uni-weimar.de
- Project presentation: **Mid-September**

SciVis-Assignments

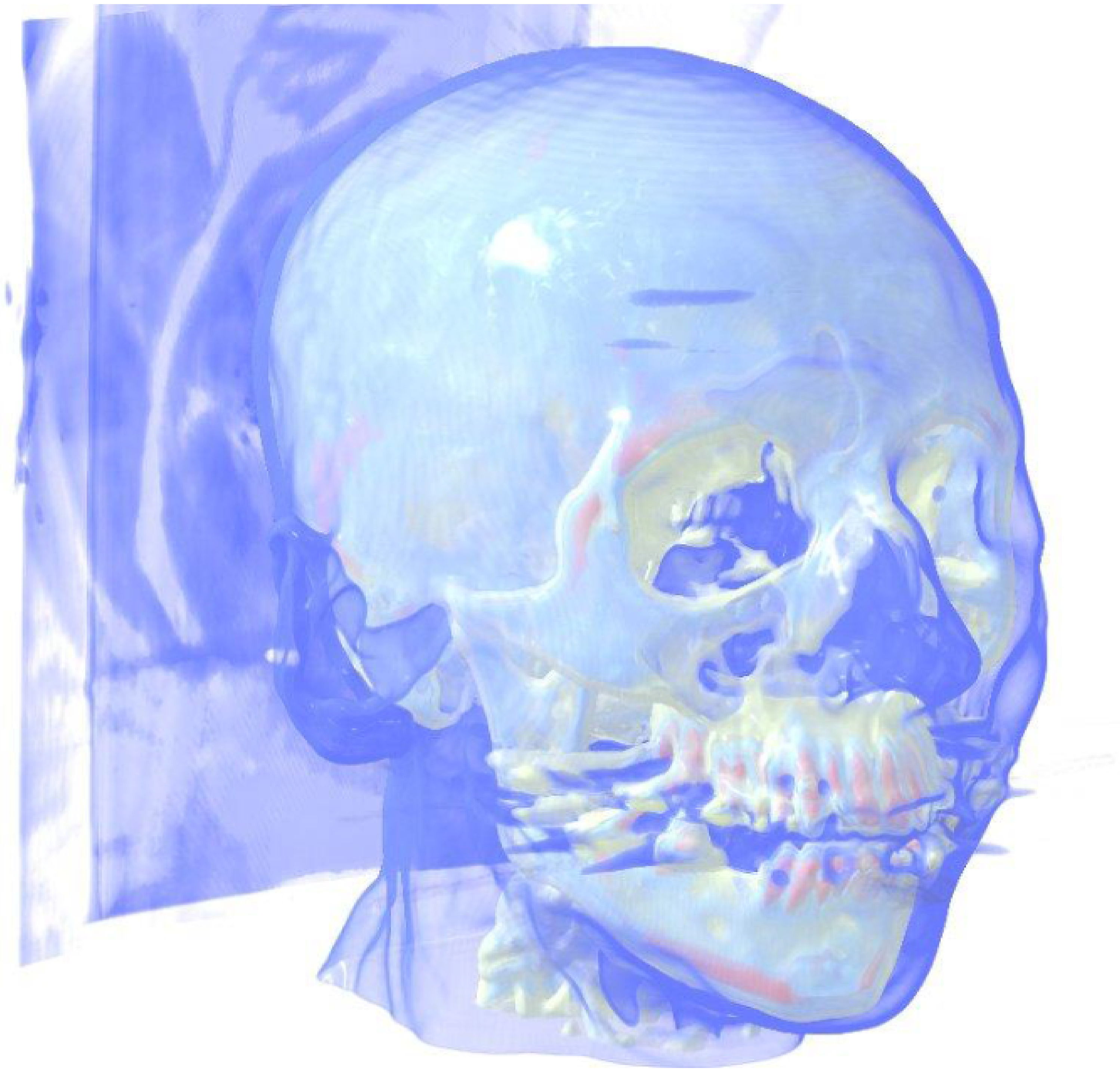
- **10 tasks, 10 points**
- Volume raycasting concepts
- Modus operandi
  GLSL, C++11, OpenGL, Cmake
- Raycaster is implemented in GLSL
- No need to touch any C++ files
- Submission:
  Lab class on Juli 3, 2018
  Lab class on Juli 10, 2018



Backup your code!

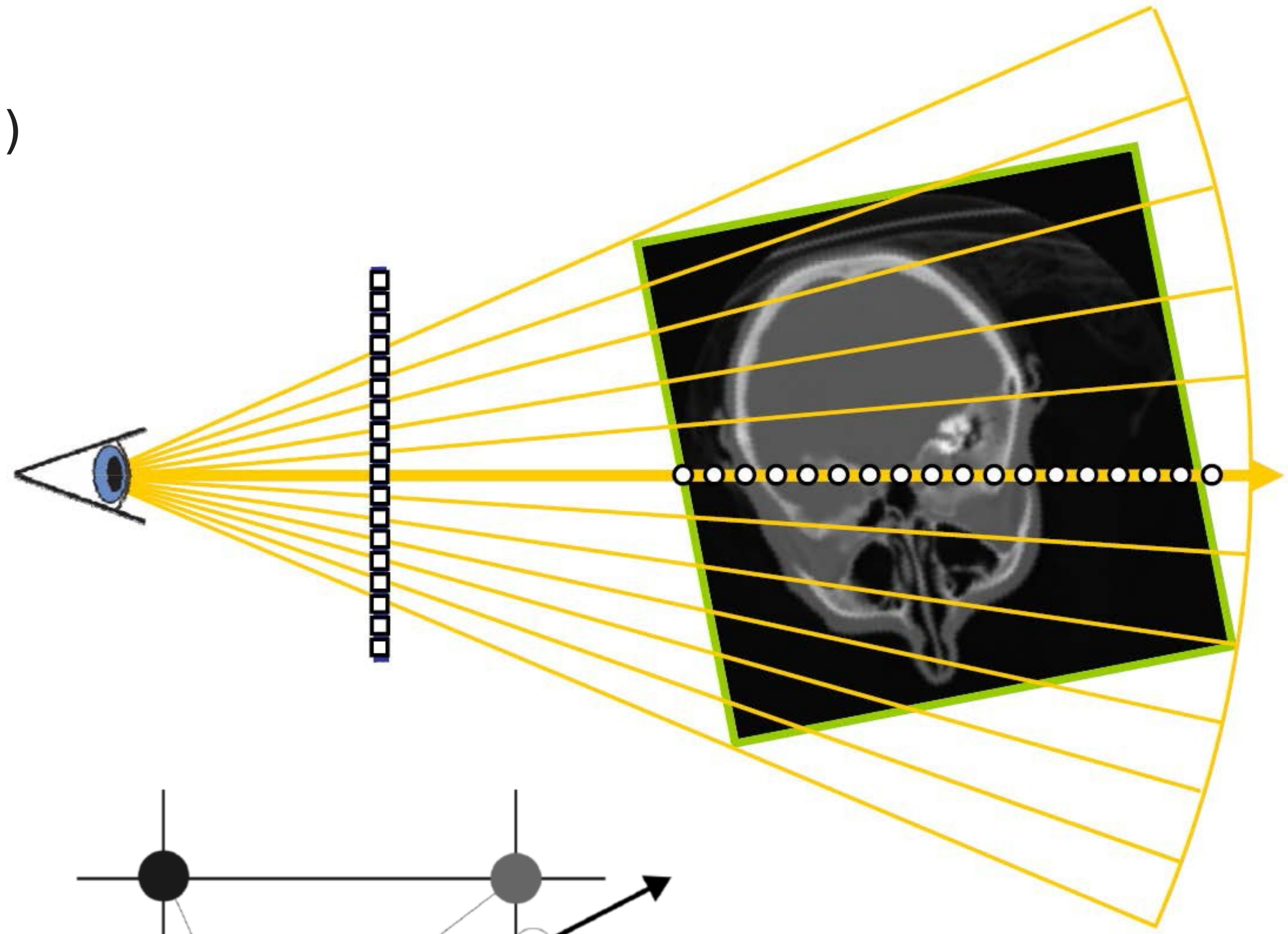
- **It is your own responsibility to backup your code!**
- Use *github*, *dropbox*, *USB-stick, your phone…*
  – whatever you feel comfortable using
- If you cannot run your code on the day of submission,
  you will fail the lab class!

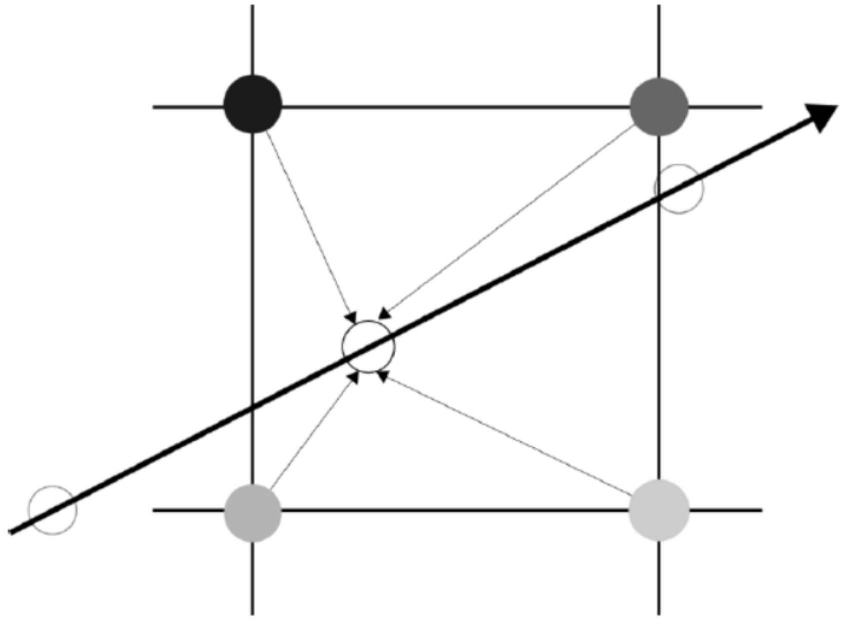
GPU-based Volume Raycasting



GPU-based Volume Raycasting

- The **volume** is stored in a 3D-Texture (1 byte per voxel)
- A **ray** is generated from each fragment
- The volume is **sampled** along each ray
- E.g. **Maximum Intensity Projection**:
  Choose the maximum of all samples along a ray to color the pixel
- Data values defined on a **regular grid**
- Sampling the volume requires **interpolation**

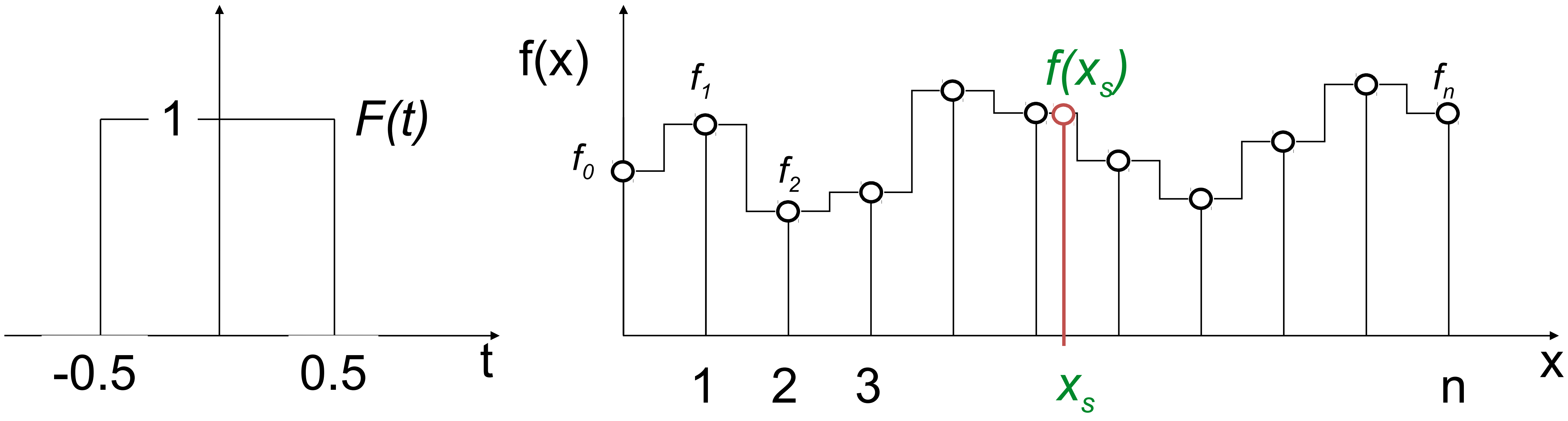




Nearest Neighbor Interpolation

- **Box-shaped** reconstruction kernel F(t)

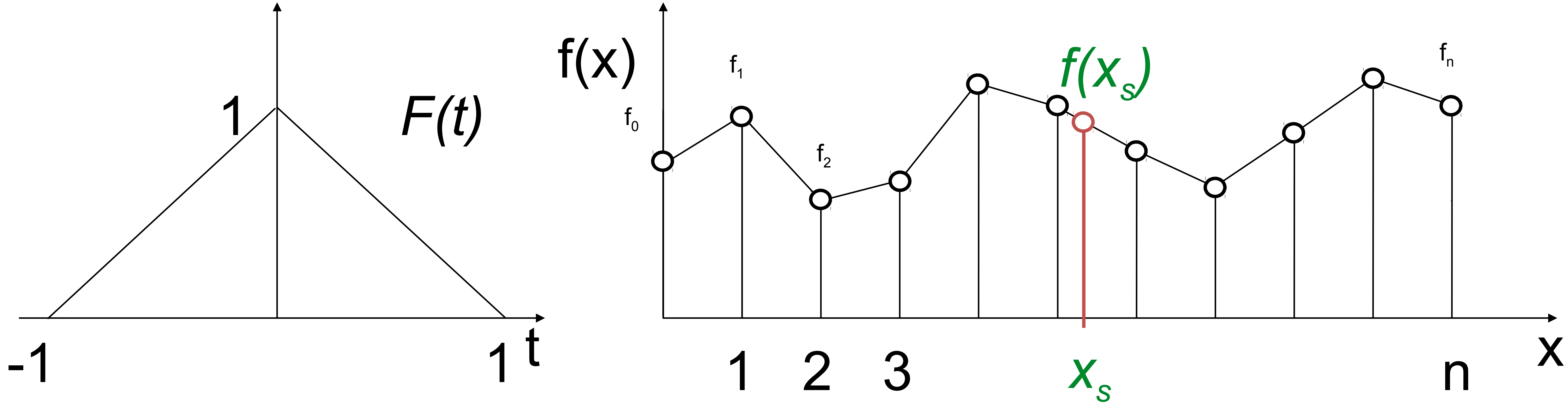
$$f(x) = \sum_{i=0}^{n} f_i F(x - i)$$



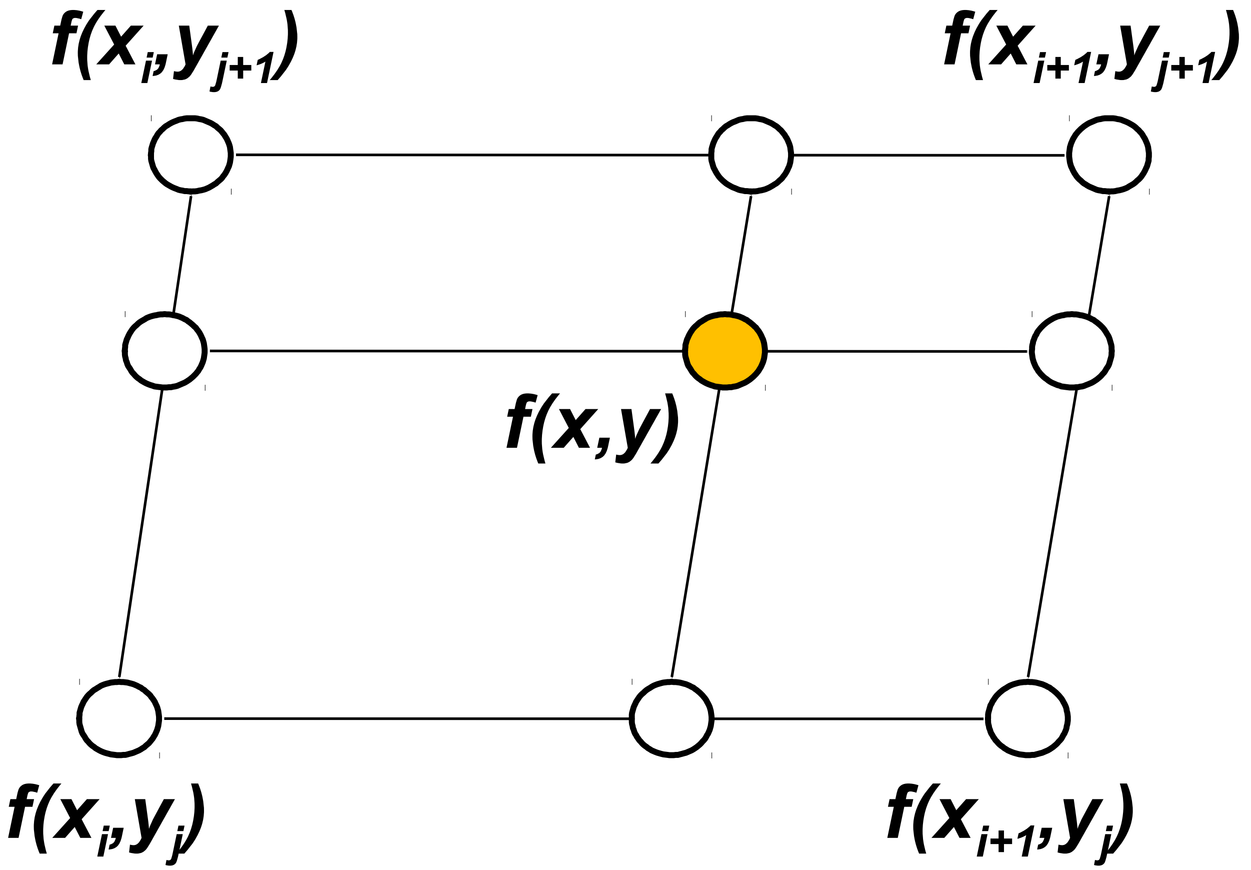
Linear Interpolation

- **Tent-shaped** reconstruction kernel F(t)

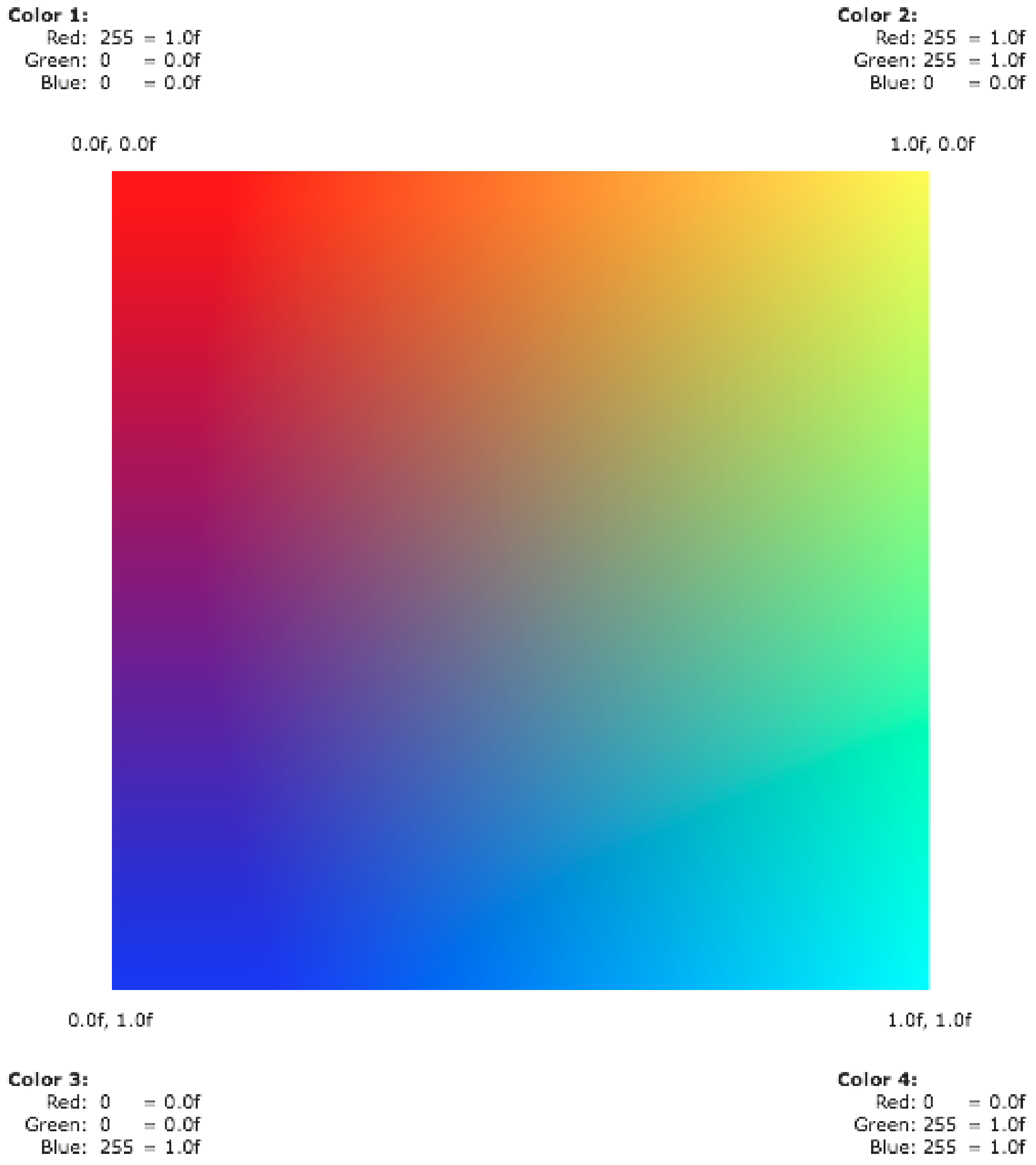
$$f(x) = \sum_{i=0}^{n} f_i F(x - i)$$



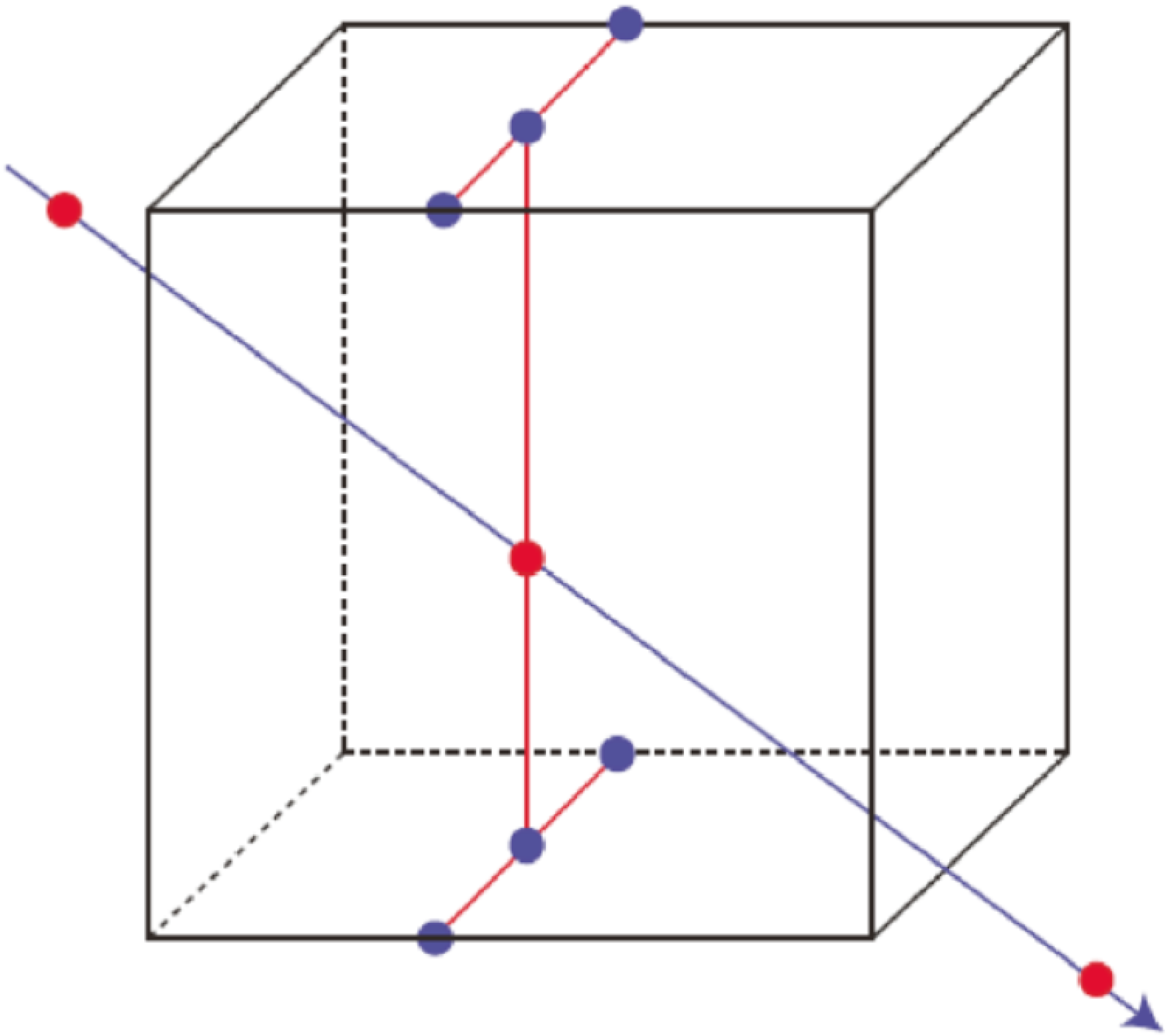
Bilinear Interpolation



$$f(x,y) = (1-v)\left((1-u)\, f(\mathbf{x_i},\mathbf{y_j}) + u\, f(\mathbf{x_{i+1}},\mathbf{y_j})\right) + v\left((1-u)\, f(\mathbf{x_i},\mathbf{y_{j+1}}) + u\, f(\mathbf{x_{i+1}},\mathbf{y_{j+1}})\right)$$



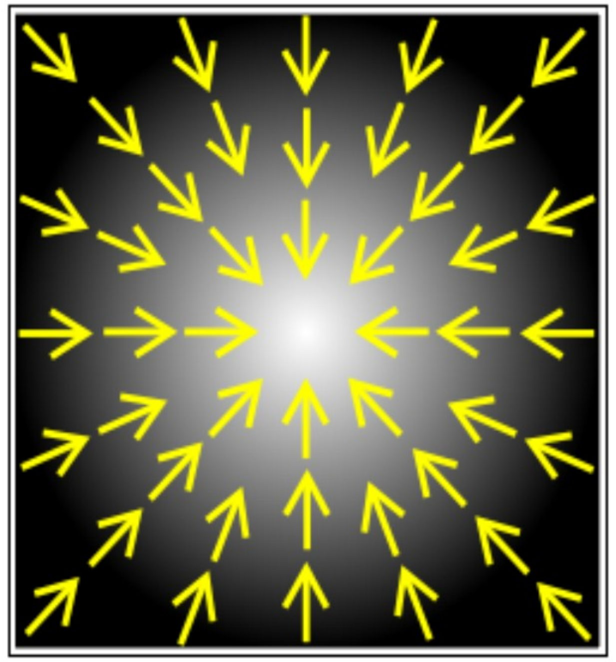
Trilinear Interpolation

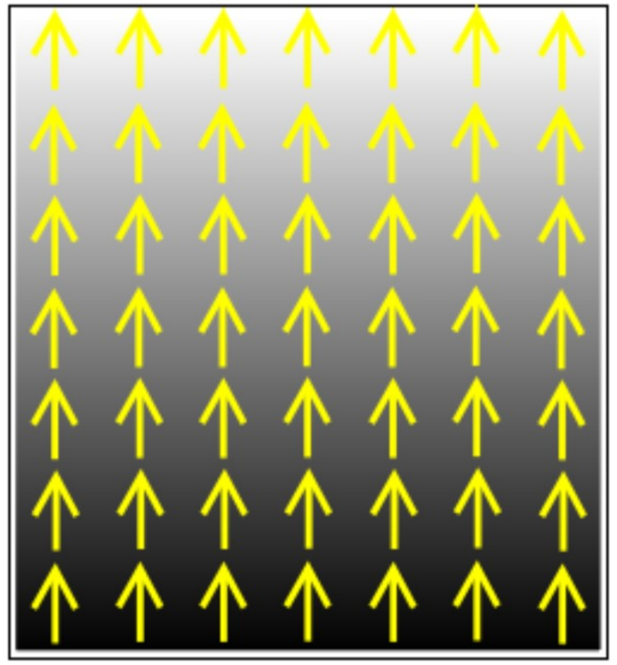


Gradient Computation

- **Gradients**
  Magnitude and direction
  Describe local changes in scalar field

- **Central difference**
  $D_x = (f(x+1, y, z) - f(x-1, y, z)) / 2$
  Fast, easy to implement but only an approximation





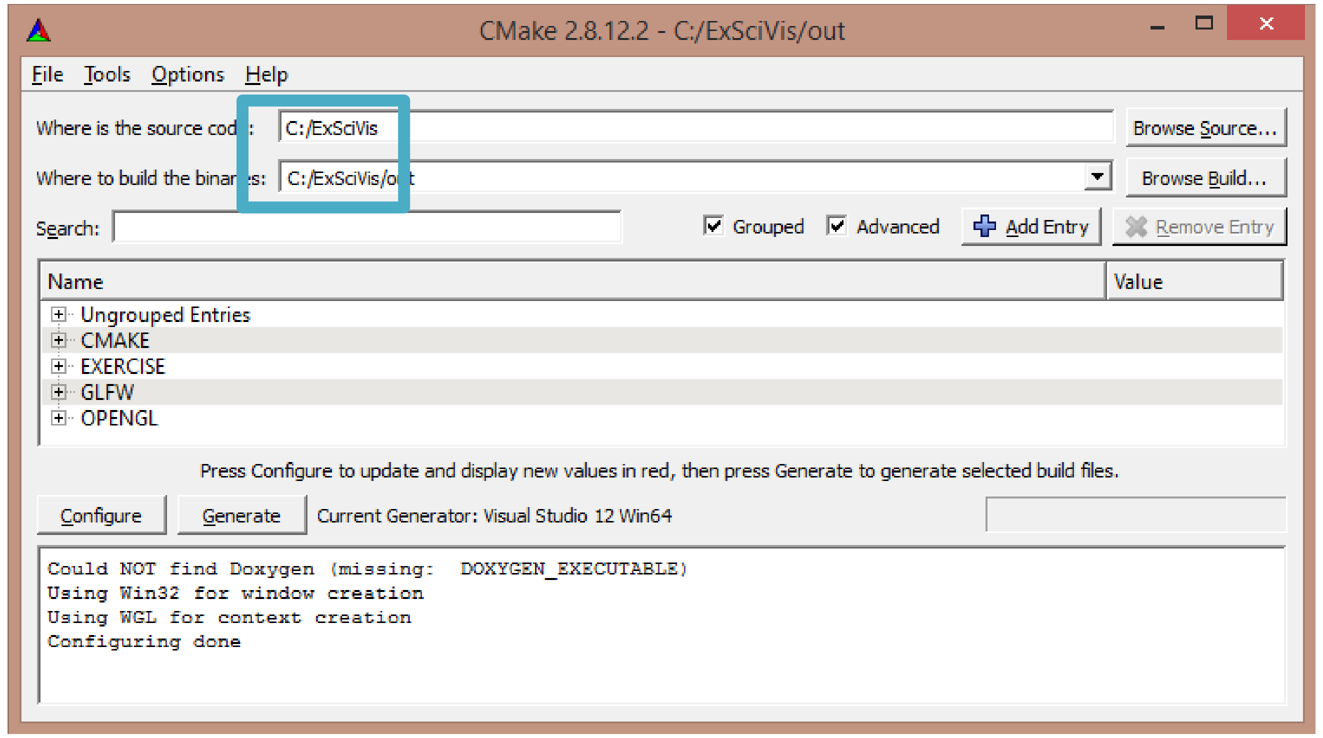
Project Setup

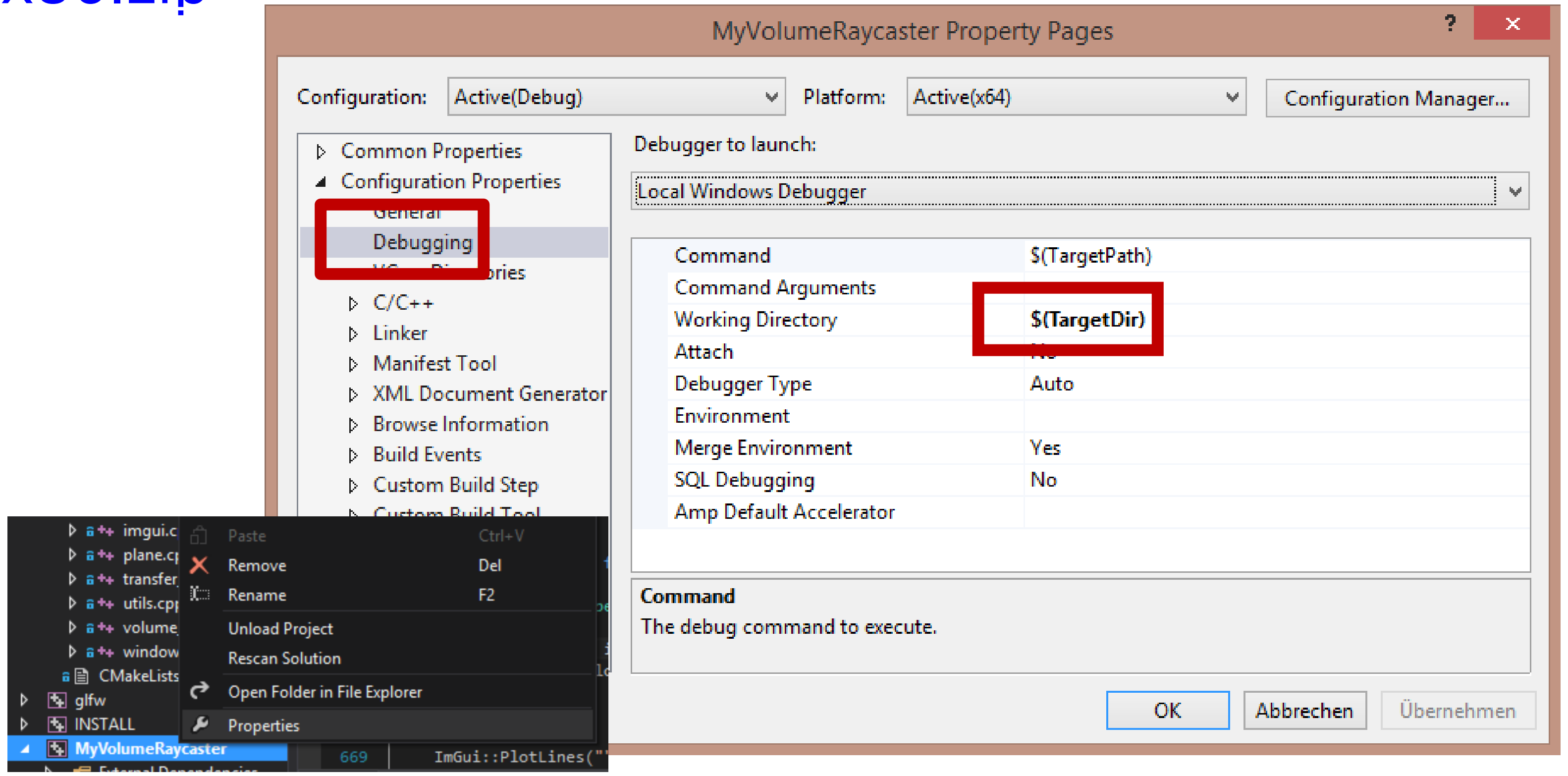
- Download .zip
  https://github.com/vrsys/ExSciVis2018/archive/master.zip

- Or fork
  https://github.com/vrsys/ExSciVis2018.git

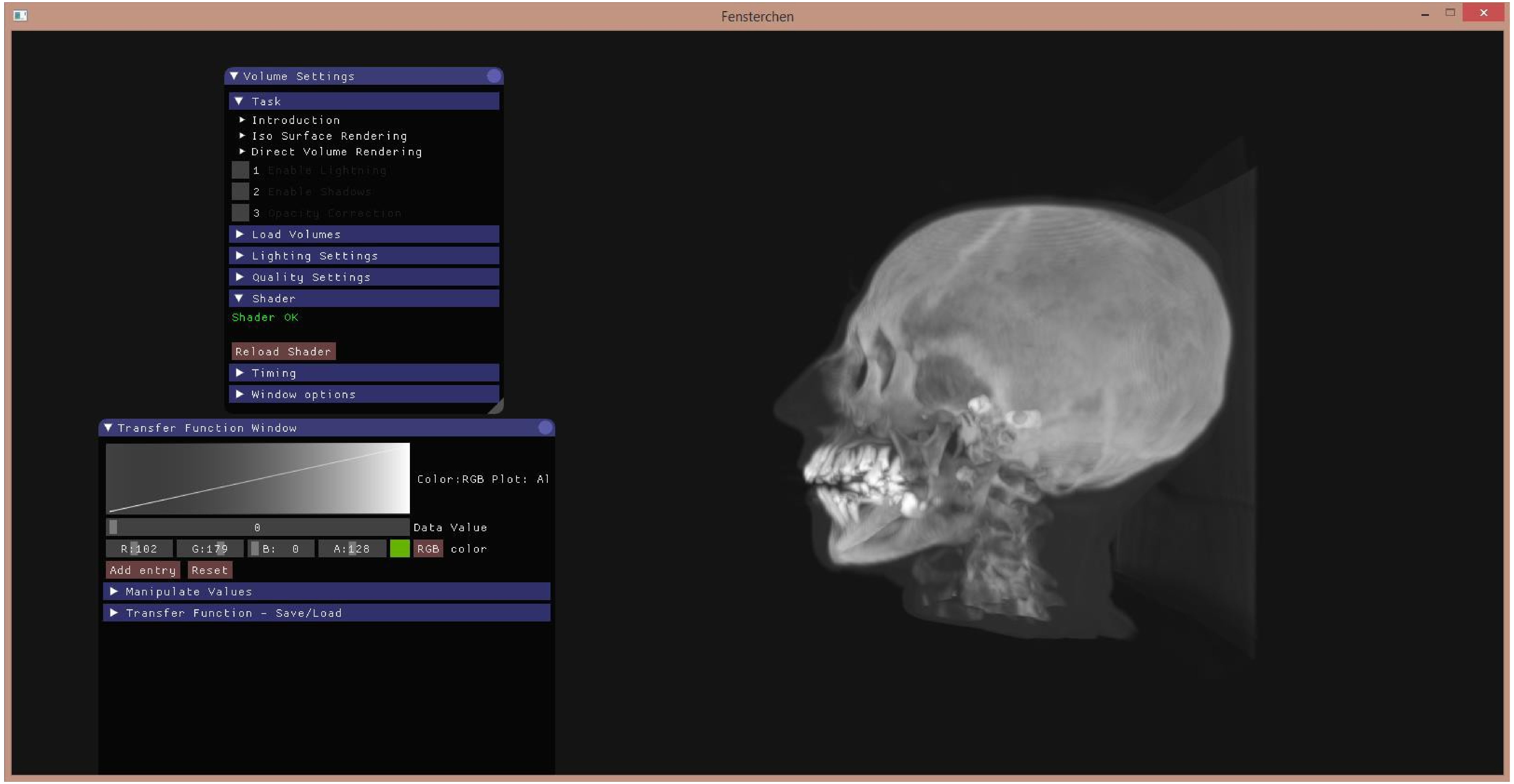
- Generate Makefile with Cmake
  Linux: Cmake is installed, use ccmake
  Windows: download Cmake
  https://cmake.org/files/v3.11/cmake-3.11.2-win32-x86.zip

- Build and run



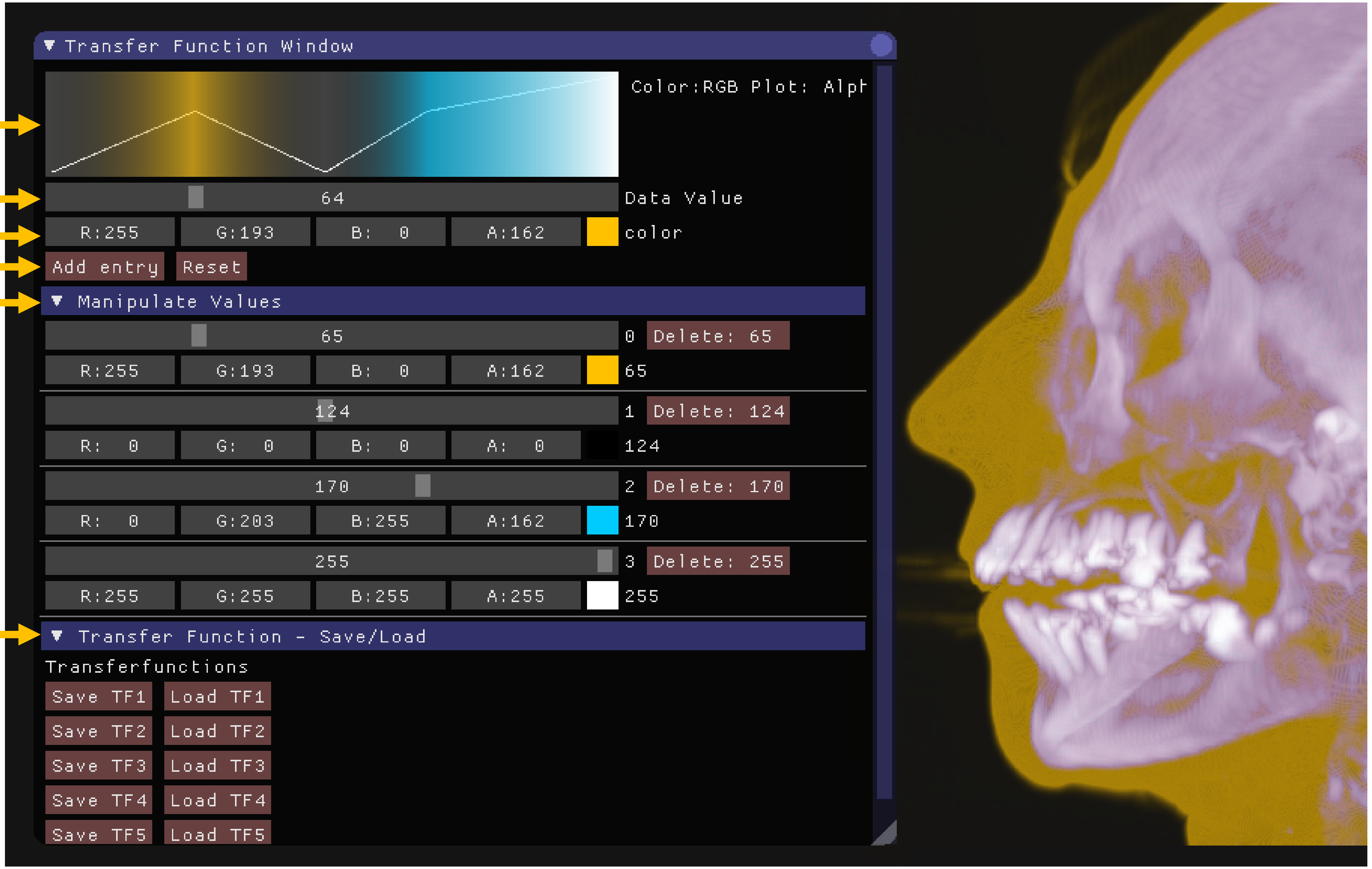


ExSciVis – First look



ExSciVis – Transfer Function Editor

- Current transfer function
- Set data value
- Set color / opacity
- Add stop
- Manipulate existing stops
- Save / Load

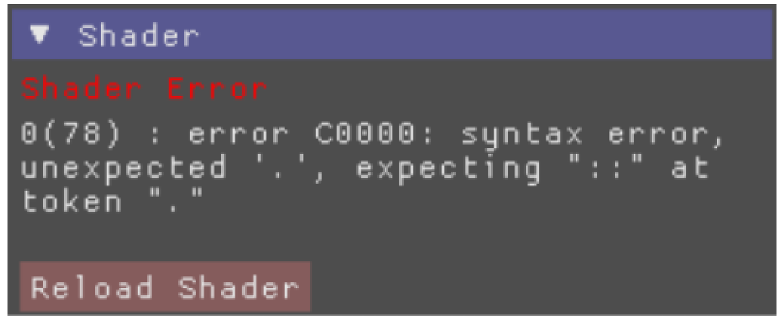


ExSciVis – GLSL

- Framework uses graphics card hardware acceleration
- Raycasting happens in **ExSciVis/source/shader/volume.frag**
- After editing this file, hit reload shader button

(no recompilation, no relaunch)

- If your code does not compile, you get a message



(program will keep running with last working shader)

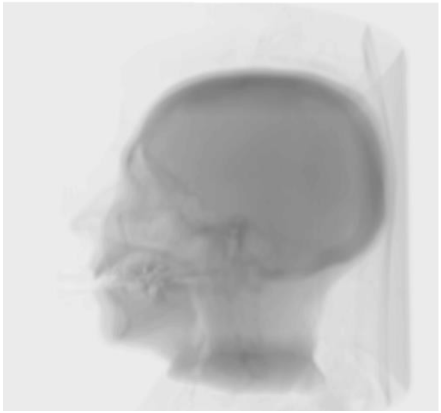
Maximum Intensity Projection

- Get data value at sampling point
- Evaluate transfer function
- Determine maximum color
- Move to next sampling position

```
#if TASK == 10
    vec4 max_val = vec4(0.0, 0.0, 0.0, 0.0);

    // the traversal loop,
    // termination when the sampling position is outside volume boundarys
    // another termination condition for early ray termination is added
    while (inside_volume)
    {
        // get sample
        float s = get_sample_data(sampling_pos);

        // apply the transfer functions to retrieve color and opacity
        vec4 color = texture(transfer_texture, vec2(s, s));

        // this is the example for maximum intensity projection
        max_val.r = max(color.r, max_val.r);
        max_val.g = max(color.g, max_val.g);
        max_val.b = max(color.b, max_val.b);
        max_val.a = max(color.a, max_val.a);

        // increment the ray sampling position
        sampling_pos  += ray_increment;

        // update the loop termination condition
        inside_volume  = inside_volume_bounds(sampling_pos);
    }

    dst = max_val;
#endif
```

Assignment 1: Isosurfaces

1. Implement *average intensity projection*. (Hint: by default, the raycaster uses *maximum intensity projection*)
   [1 Point]



2. Implement a *first-hit* ray traversal scheme for variable thresholds to visualize *isosurfaces*.
   [1 Point]

3. Improve the intersection search using a *binary search* method. (Hint: do this after assignment 2, task 2 to see the difference)
   [1 Point]

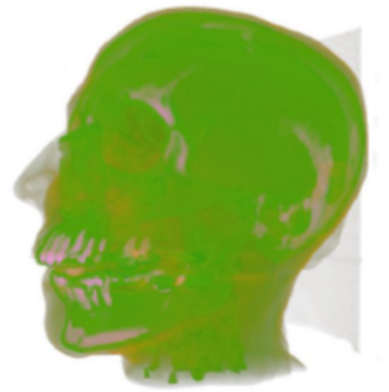
Assignment 2: Shading

1. Implement a function get_gradient() to calculate the gradient at a given volume sampling position. (Hint: central differences method suffices).
   [1 Point]

2. Determine the *surface normal* for the found intersection point and calculate a basic illumination for the iso-surface. (Hint: Color-code and visualize your normals to make sure they are correct. A simple *phong shading model* suffices)
   [1 Point]

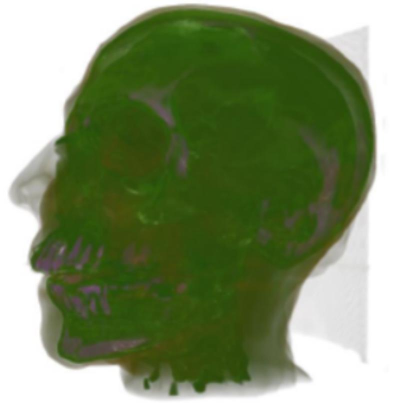
3. Extend the illumination calculation for the correct display of surface shadows.
   [1 Point]

Assignment 3: Compositing



1. Implement a *front-to-back compositing* traversal scheme
   [1 Point]

   Implement a *back-to-front compositing* traversal scheme
   [1 Point]



2. Use the generated volume gradients to calculate the local illumination for the volume samples during the compositing.
   (Hint: simple *phong shading model* suffices)
   [1 Point]

3. Extend the compositing algorithm with *opacity correction*.
   [1 Point]

Optional Assignment

1. Based on the solution of assignment 3, implement *pre-integrated* volume rendering.
   [optional, 4 Points]