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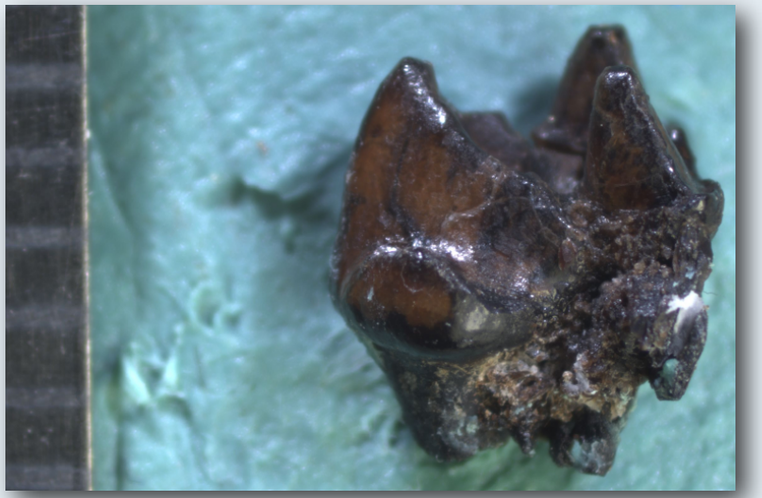
Interactive generation of (paleontological) scientific illustrations from 3D-models

Sebastian Schäfer, Christoph Knopp, Detlef Krömker

Goethe-Universität Frankfurt

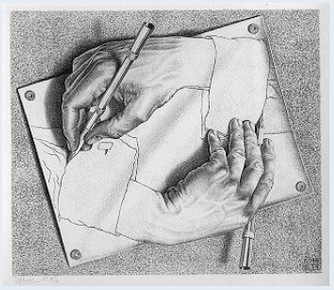
Motivation: from artifact to illustration

Photo of Leptictidium tooth



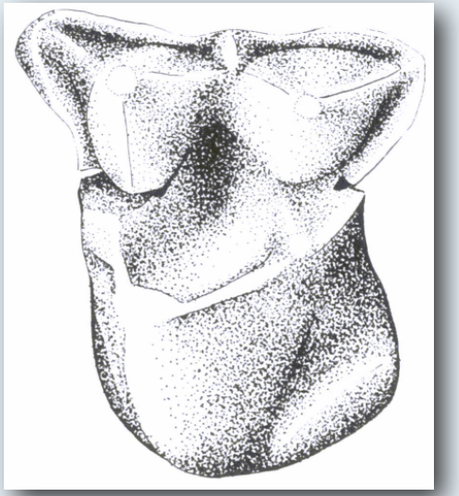
[C]

[A]



[B]

Scientific illustration and schematic drawing



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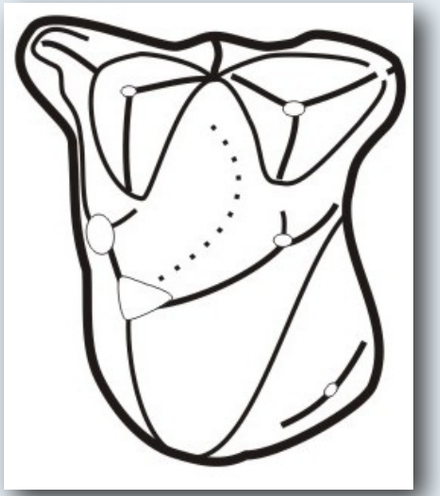

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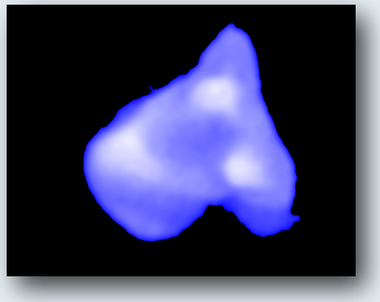
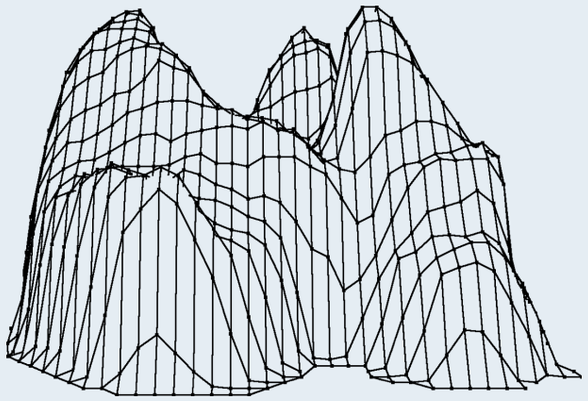
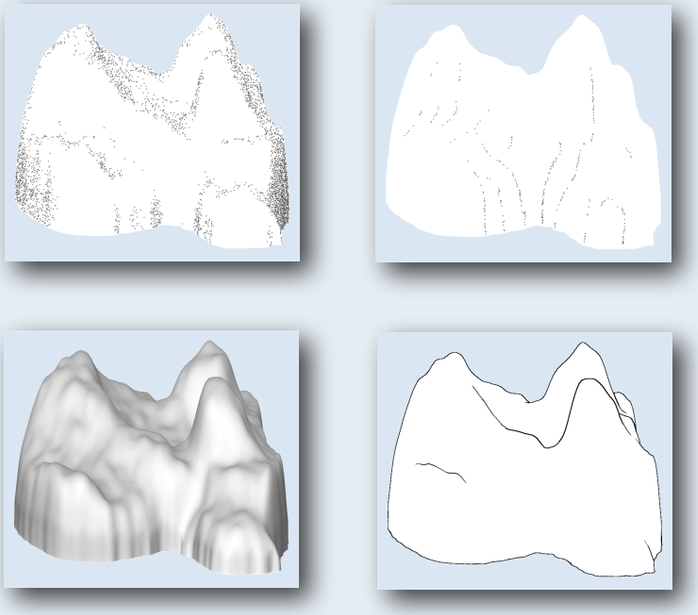
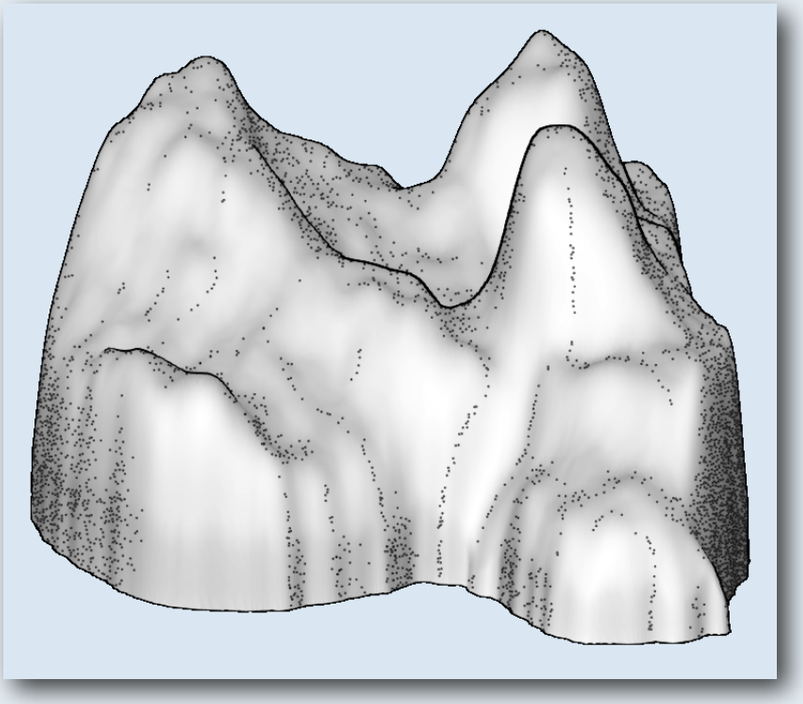




Reconstructed heightmap and 3d-mesh



4 layers: 2x stippling, shading, outlines



Final rendered scientific illustration

Outline

- Background
- Overview
- Details
- Examples
- Future work

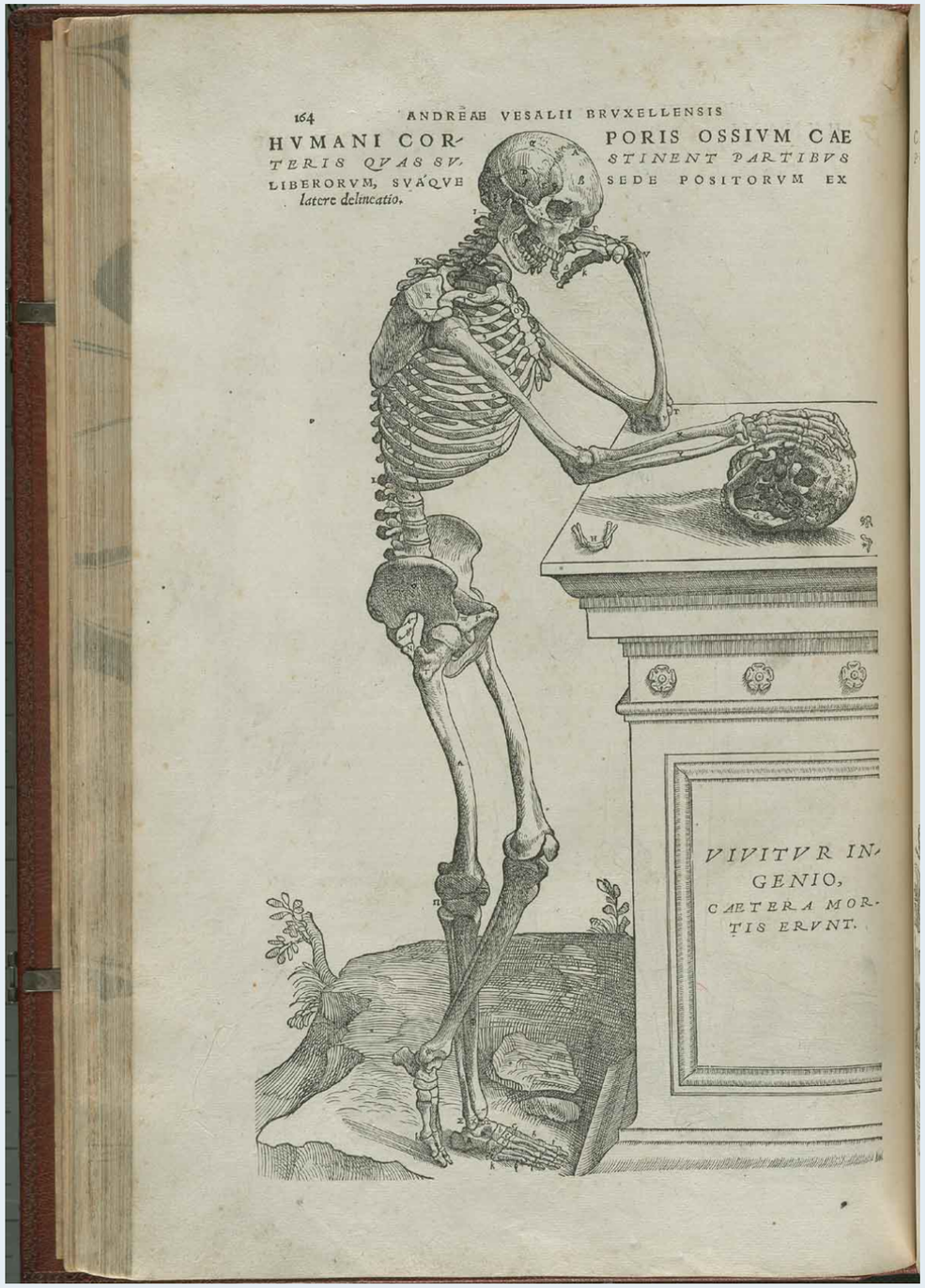
Background

Illustrations & NPR

Background - Scientific Illustrations

Scientific Illustrations:

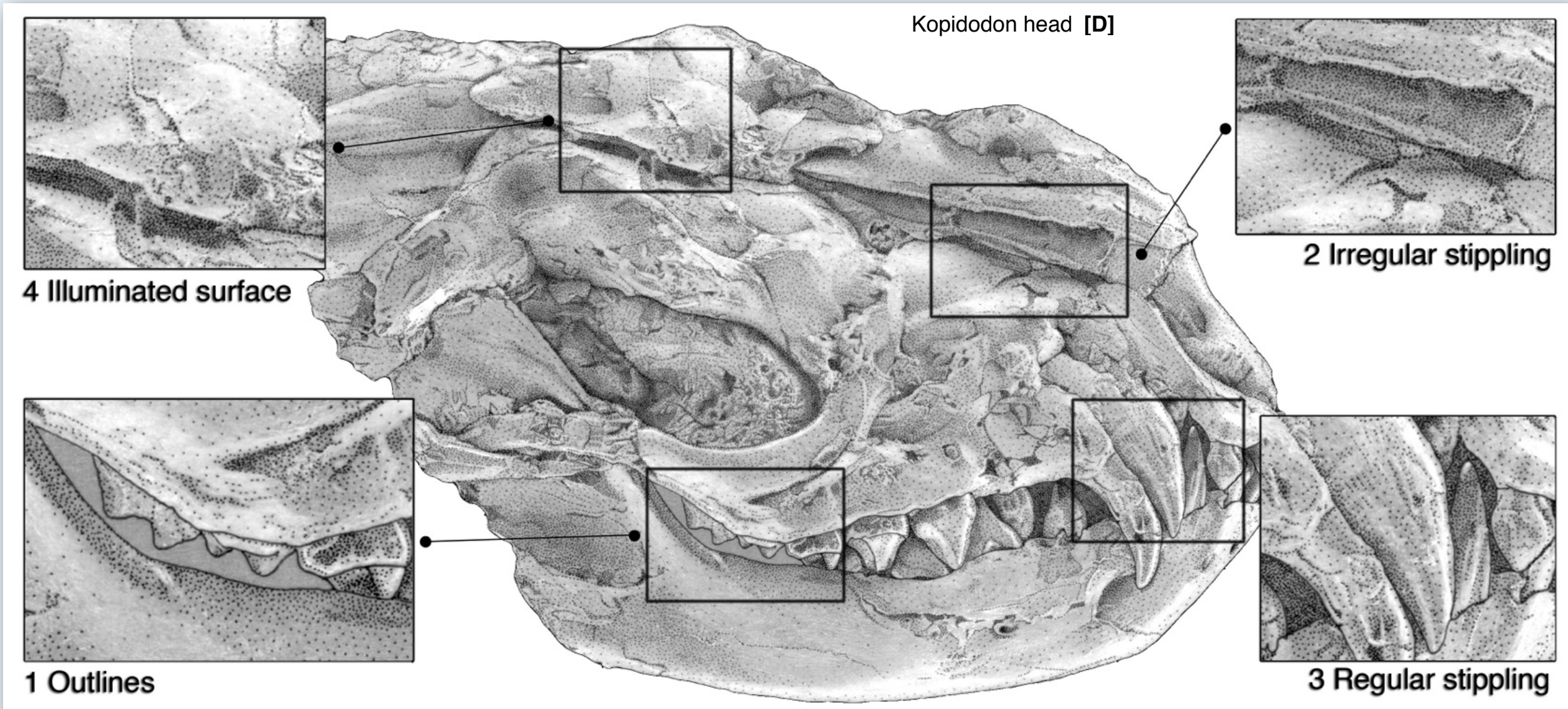
- to illustrate:
  "to provide with visual features intended to explain or decorate" (Merriam-Webster)
- to illustrate: *"to know what not to draw" (Illustrator)*
- Often depict an **abstract object**
- Show or **enhance features** of the object
- **Leave out unimportant** details
- Drawn **manually** in time-consuming task
- Highly **subjective**, form of art
- Needed **even today** for publications in Medicine, Paleontology, Biology, Archaeology, ...



Medical Illustration from 1543
Vesalius: De humani corporis fabrica

[E]

Background - Example analyzed



1. **Outlines** - mark the silhouette or overlapping object parts with lines

Background - NPR

- NPR = Non-Photorealistic Rendering

- Well researched for > 2 decades, developed techniques for styles include
  - **Stippling**
    - **Blue Noise Wang-Tiles**, Stippling by example, Voronoi Stippling, **Electrostatic Halftoning**, ...
  - **Outlines**
    - **Image Enhancement, Edge detection: 1st and 2nd order**, ...
  - **Expressive Shading** - use different illumination functions that emphasize structure
    - Exagerrated Shading, Dynamic Stylization of Shading primitives, ...

Overview

Goals, Method & Pipeline

Overview - Goals

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- Input: **3d-models** (or heightmap)

- Interactive Rendering (see changes applied in a "**timely manner**"):
  - Tweak parameters, adjust camera, ...

Interactivity

- Use **NPR-Algorithms**:
  - Adjust & tweak parameters (interactive)
  - combine as desired

NPR Algorithms

- **Artistic freedom** / subjective illustration
  - manipulate model
  - correct results
  - process manual input

Artistic Freedom

- **High DPI** output preferred ~300dpi

Overview - Method

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Interactivity

- Utilize **GPU** for efficient rendering:
  - Use RenderTargets, Screen-Space image filters, ...
  - Prefer GPU-Algorithms over CPU if quality is acceptable

NPR Algorithms

- Use **layers** to show features with NPR-Algorithms
  - Allow free adding & arrangement

Artistic Freedom

- Use a “**painter**”-feature in 3D-view for abstraction

  a)modify object and

  b)modify results shown on layers.

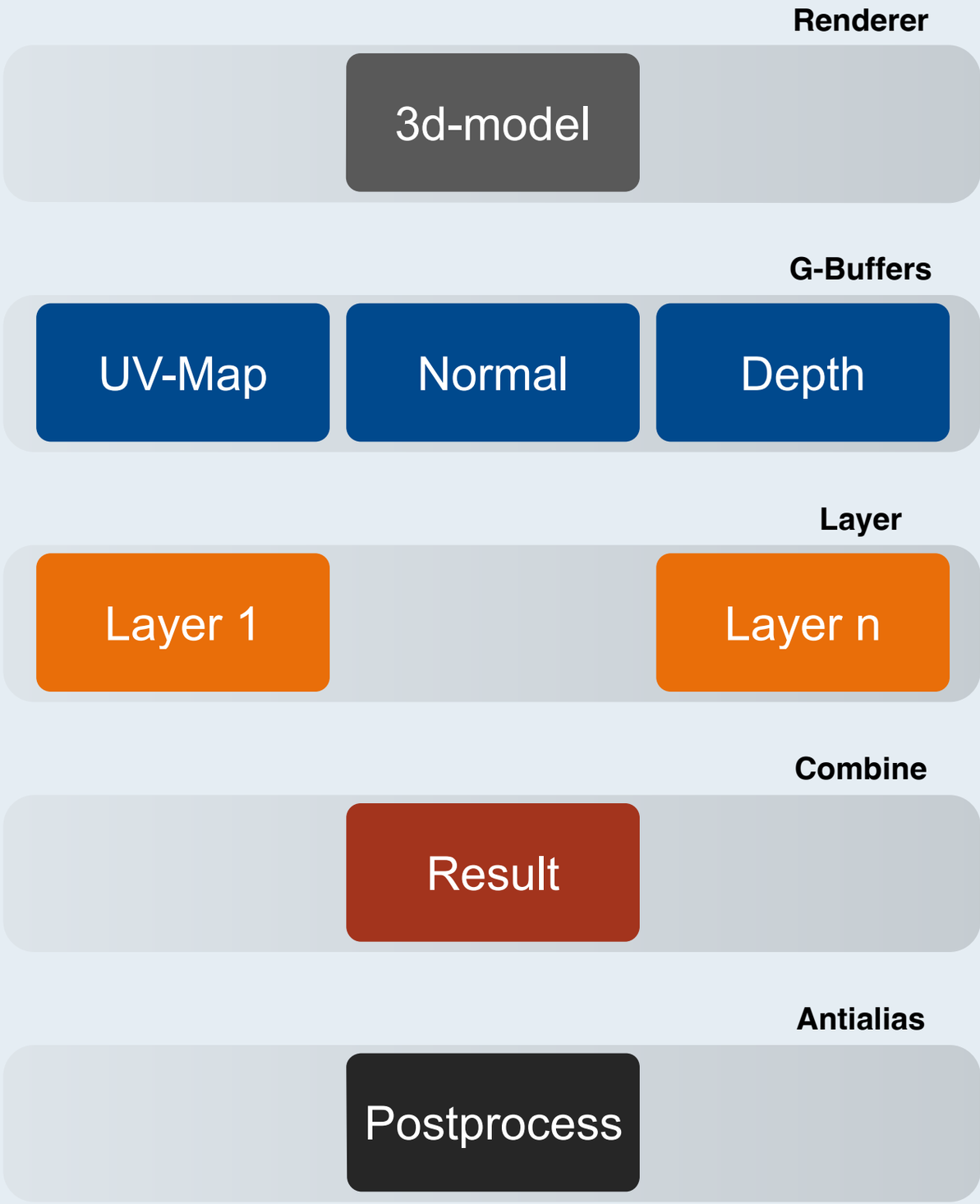
Overview - Pipeline

- Render object into G-Buffers
  - starting point for NPR-Algorithms

- Render & Combine layers
- Antialias result image

- Render high res -> sample down to screen
- Zoom with scrolling window

- Behind the scenes
  - Mange Rendertargets & Layers drawn
  - C++, OpenGL 3.2 core, GLSL 1.5



Details

Layers & Painter

Details - Layers

- Capture “use specific drawing-style for a feature” idea
- Can depend on other layers, g-buffers, images, ...
  - illumination -> modify by painter -> stippling -> modify by painter
- Rendered onto RenderTarget with display-params:
  - Alpha, Colormapping & Tonecurve (brightness, contrast, gamma)
- Freely added, removed & arranged

Details - Layertypes

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Illumination

local surface illumination
- so far only diffuse -

modified Lambert, Oren-Nayar

Ambient occlusion

simulate global illumination using a darkening factor

SSAO: Crytek, Horizon-based

Stippling regular

evenly distributed points
using a particle system

Fast Electrostatic-Halftoning

Stippling irregular

unevenly distributed points
with blue noise characteristics

Recursive Wang tiles for real-time blue noise

Outlines

silhouettes & split overlapping parts

Image enhancement by unsharp masking the depth buffer, Edge detection

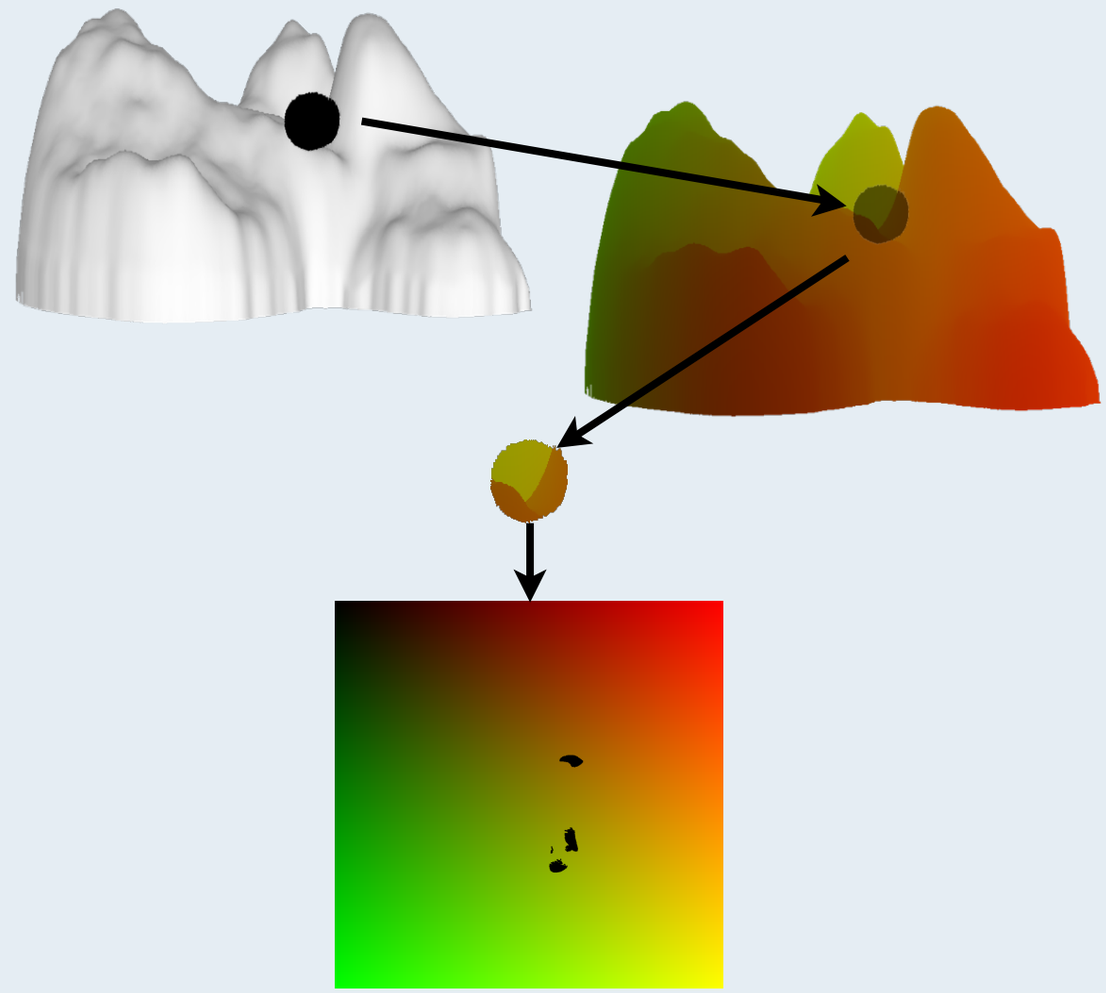
Painter: freehand, vector & bezier


manipulation & artistic “correction”

Inspired by a) ZBrush b) High Performance Interactive Painting On the GPU

Details - Painter

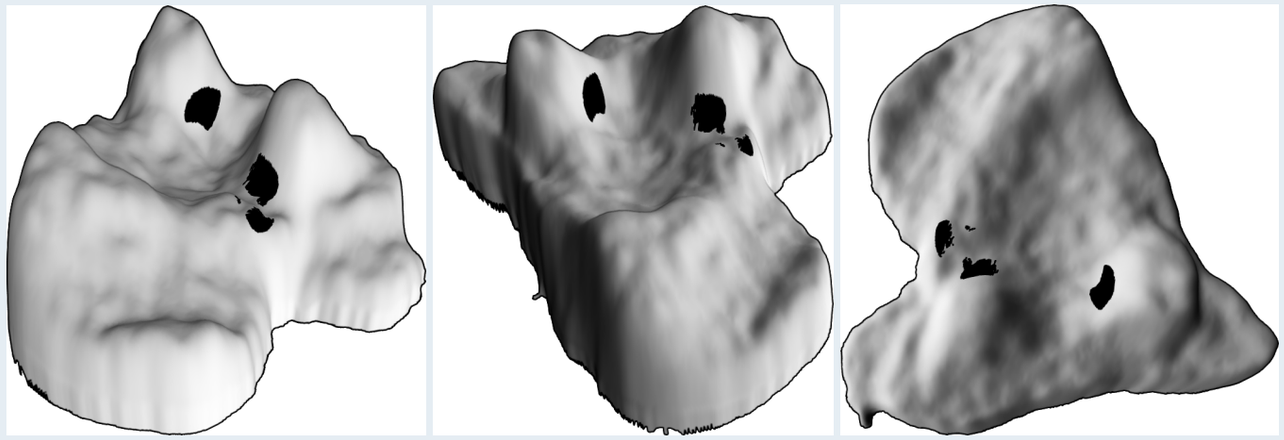
- allows to modify 3d-model (abstraction),
- adds or modifies features to be shown.



- Draws into screen-space- or surface-textures.

Painter works completely on the GPU:

- read texture-coordinate under cursor:
  store uv-coord in rg-channel of PBO
- treat PBO as VBO:
  texture-coordinate = color = position,
- draw VBO as point-primitives onto texture.

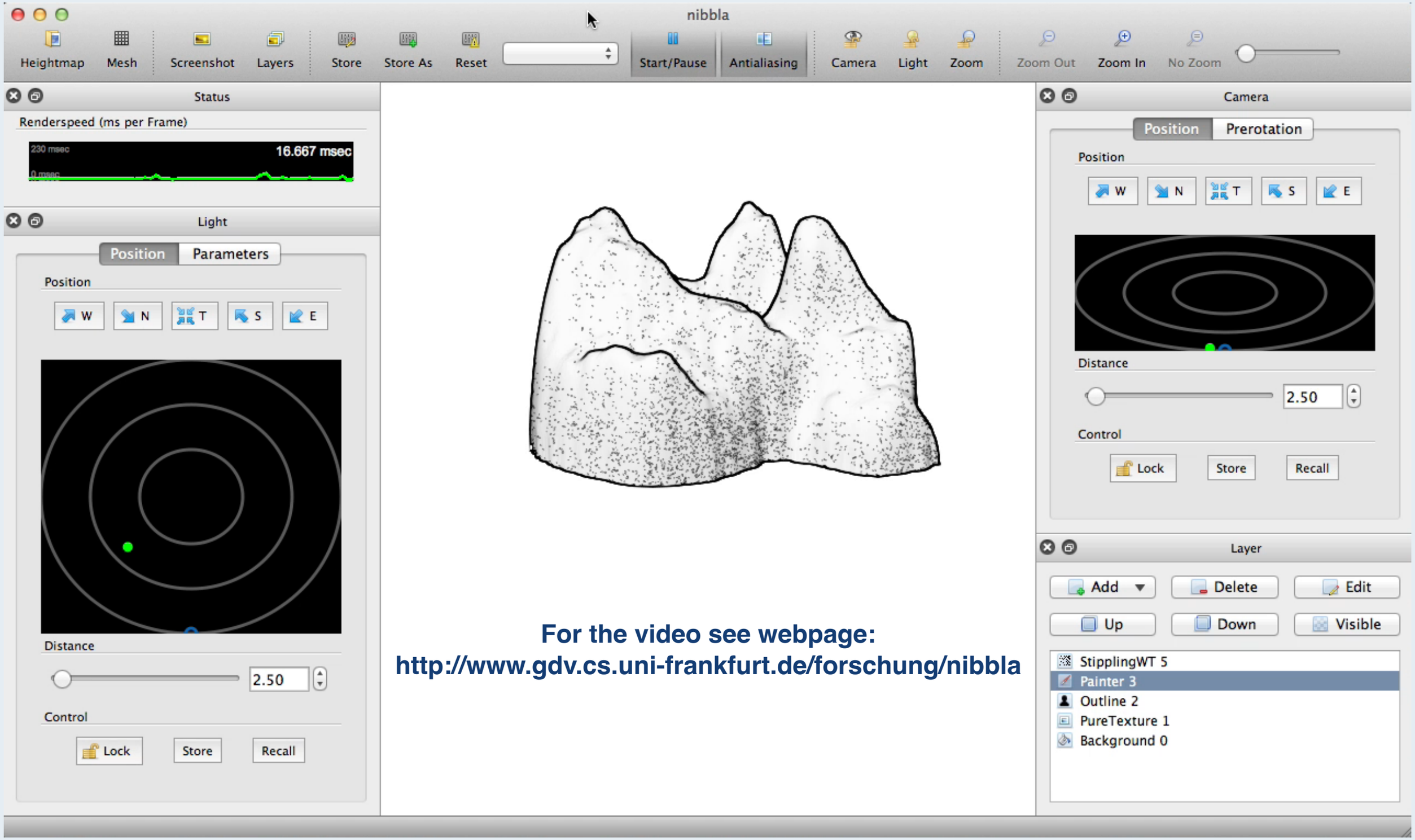


3d-painter using a surface-texture

Examples

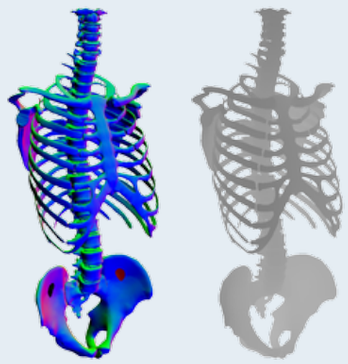
Simple Video &
Complex example

Examples - Screenshot

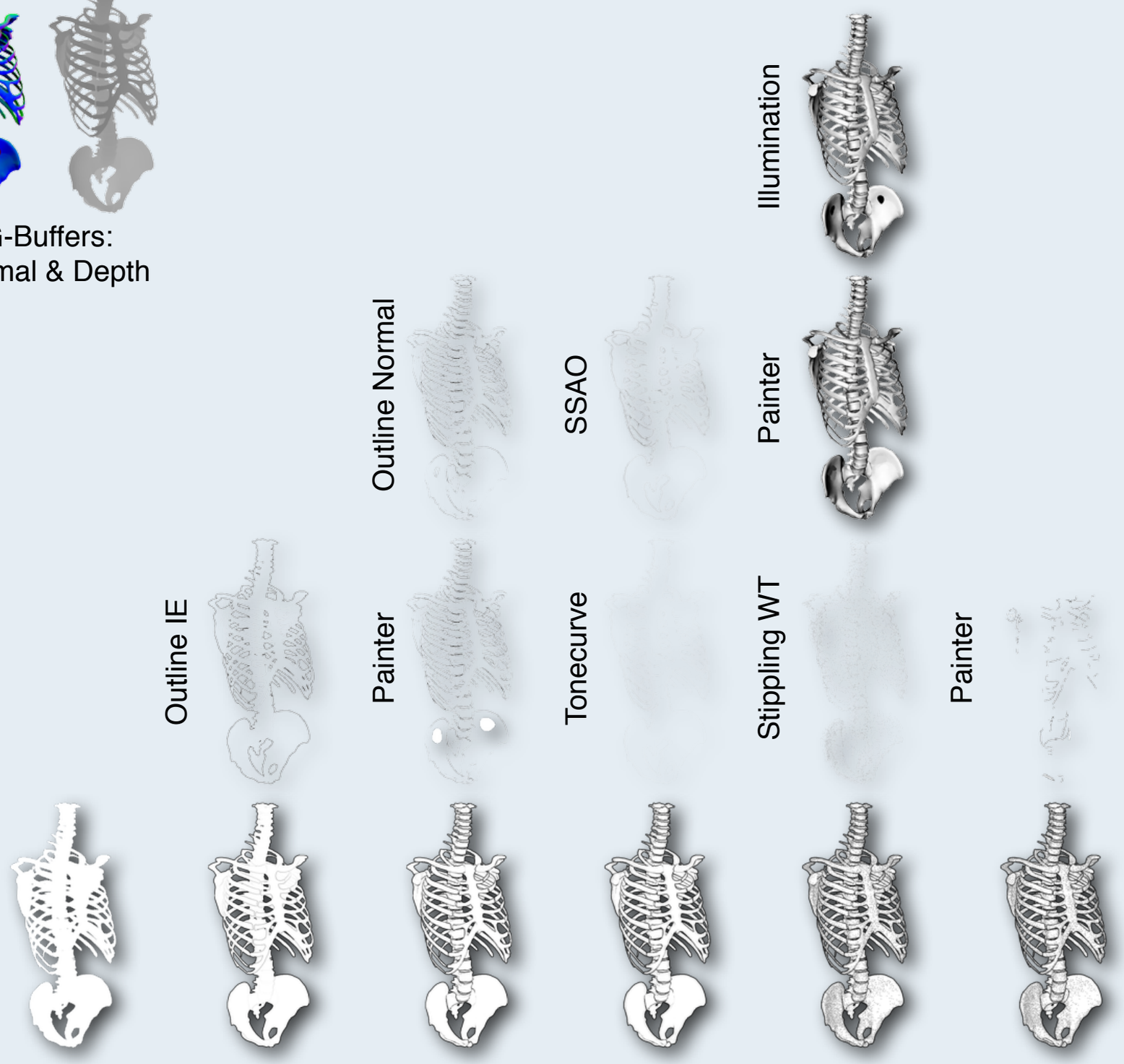


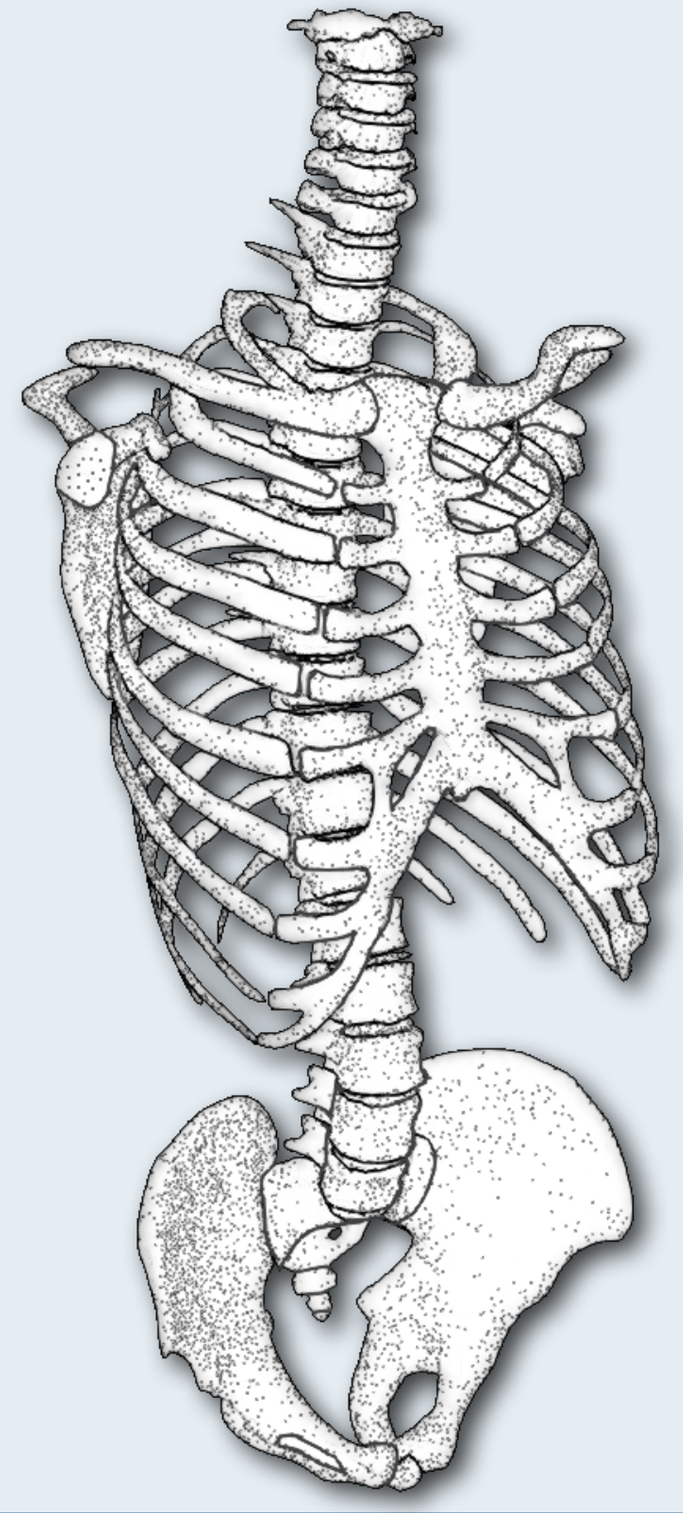
For the video see webpage:
http://www.gdv.cs.uni-frankfurt.de/forschung/nibbla

Examples - Complex Torso Example



G-Buffers:
Normal & Depth





Future Work

Validate hypotheses
Add more features

Future Work - Validate hypotheses

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- Illustration is a sketch

  The illustration created by a non-illustrating paleontologist is a sketch so he/she can discuss a “real” illustration with an illustrator.

- Illustration is publishable

  The illustration created by a non-illustrating paleontologist satisfies the requirements set for scientific illustrations.

- Illustrations for other domains can be created

  Non-illustrating researchers from other domains can create scientific illustrations using the tool (sketch or publishing criteria!).

Future Work - Continue Development

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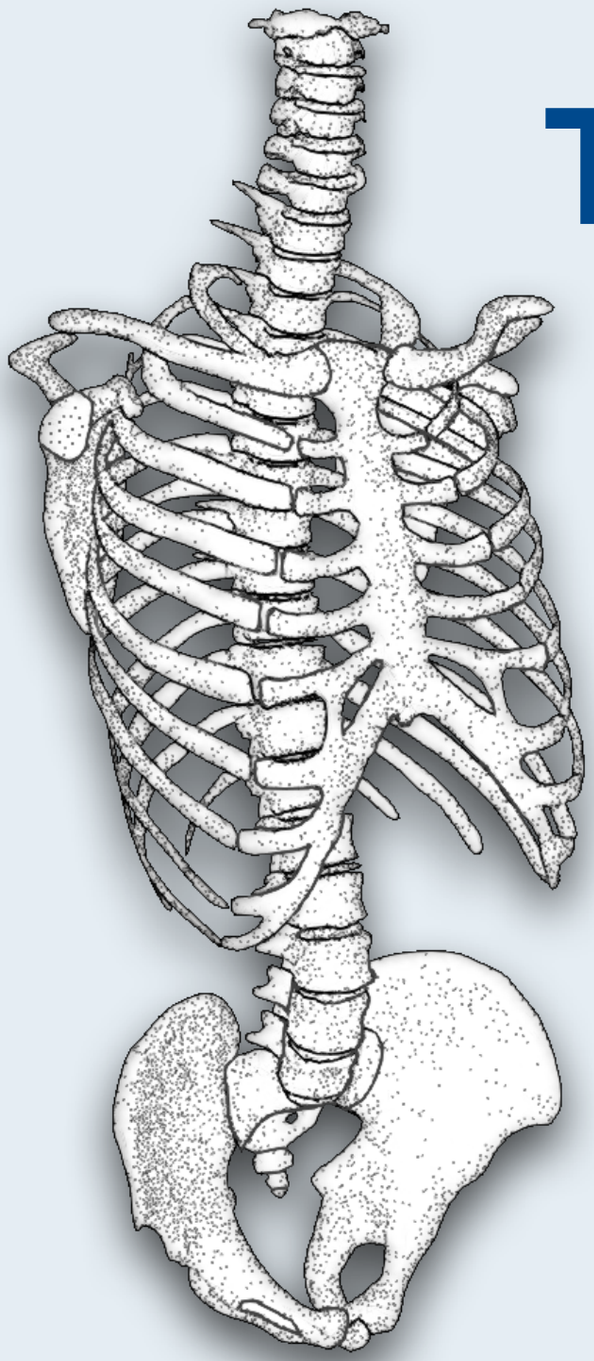
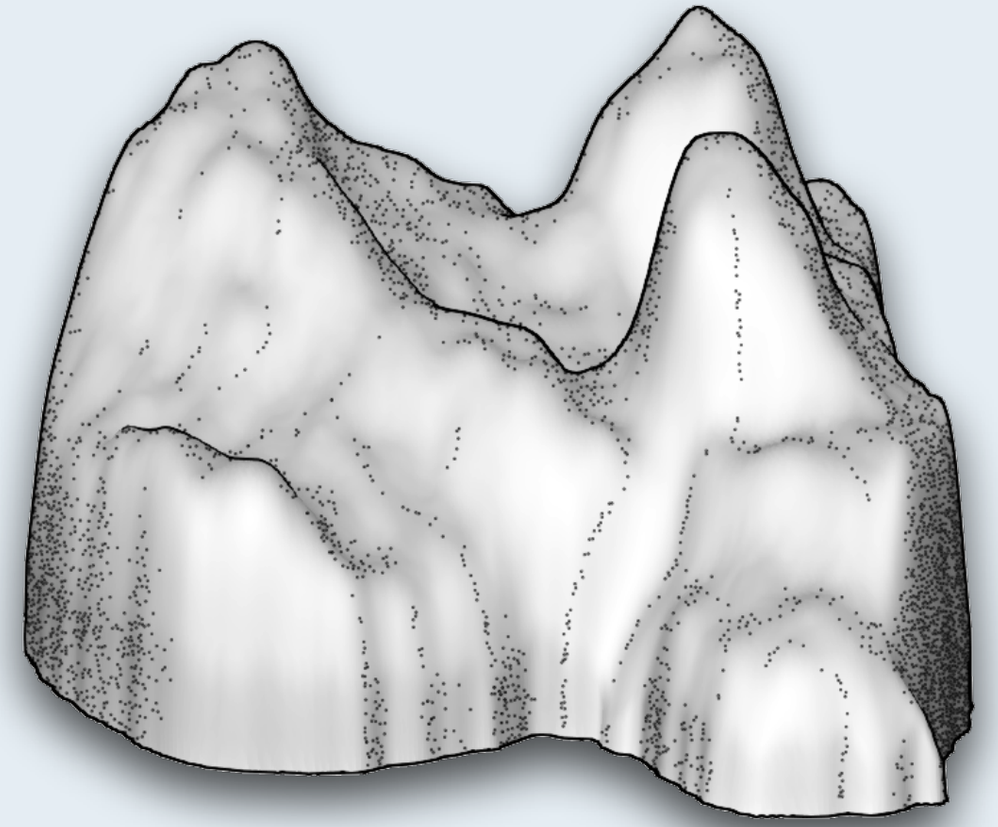
- Voxel renderer for volumetric data (esp. medical domain)
- Colored models - useful for medicine
- More drawing-styles:
  - Hatching, Line drawing, ...
- More layers:
  - Combine layers, Filter chains, ...
- Far future: Animation?



Thank you for your attention!



Images

[A] **http://thenounproject.com**

[B] **“Drawing Hands”, M. C. Escher, 1948**

[C] *Leptictidium m3*, **Dr. Thomas Lehmann, Senckenberg Research Institute and Natural Museum Frankfurt**

[D] *Kopidodon*, **Juliane Eberhardt, Senckenberg Research Institute and Natural Museum Frankfurt**

[E] **“De humani corporis fabrica” page 164, A. Vesalius, 1543**