# Interactive Volume Rendering based on a “Bubble Model”

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# Motivation

- Fast volume previewing
- No a priori knowledge about the data
- Avoid time-consuming specification of an appropriate transfer function
- Visualize preferably all the internal structures
- Interactive frame rates on low-end HW
- Fully interactive control of the rendering parameters



# Traditional methods

- Indirect volume rendering - “Marching Cubes”
  - computationally expensive preprocessing
  - which iso-surface represents the data best?
  - 3D graphics HW is required for fast rendering
- Direct volume rendering
  - time-demanding transfer function specification
  - HW acceleration is required for fast rendering

# Simplification of the general visualization model

General model [Max 95]:

$$I = I_0 \prod t_i + \sum c_i \prod t_j$$

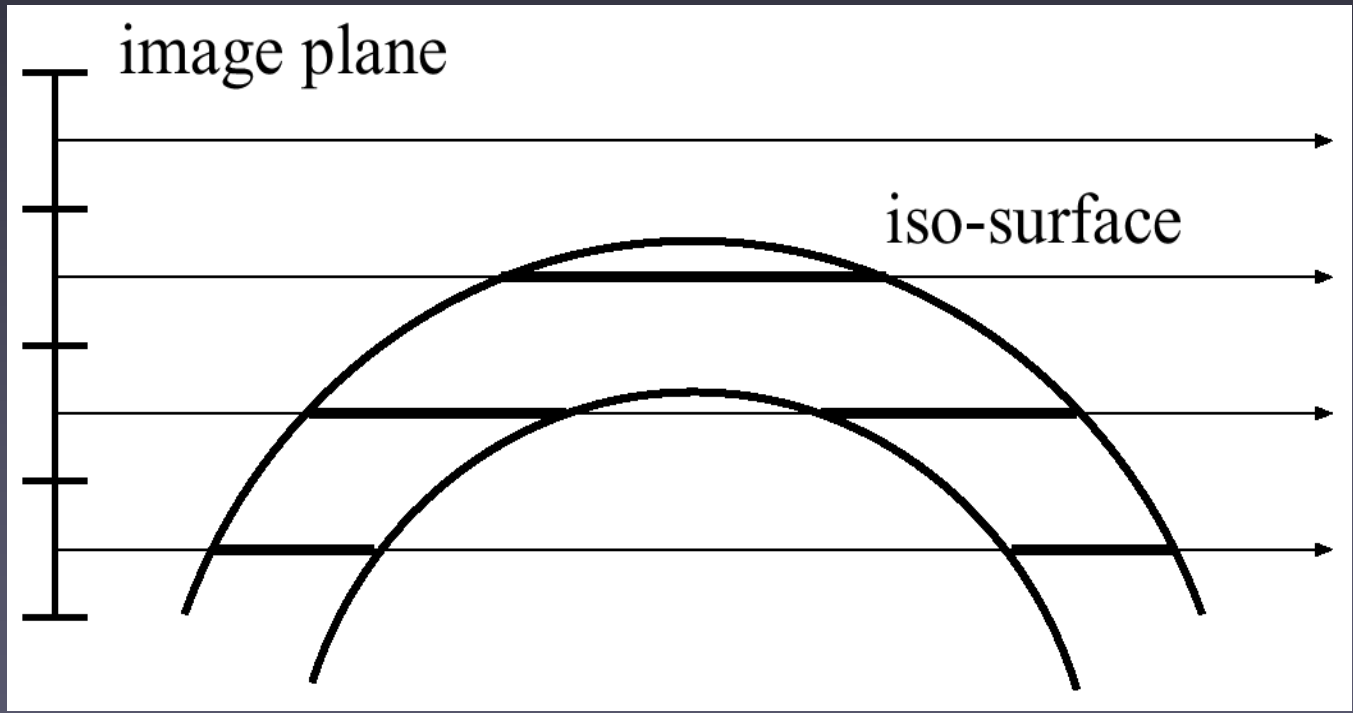
Simplified model:

$$I = I_0 \prod t_i$$

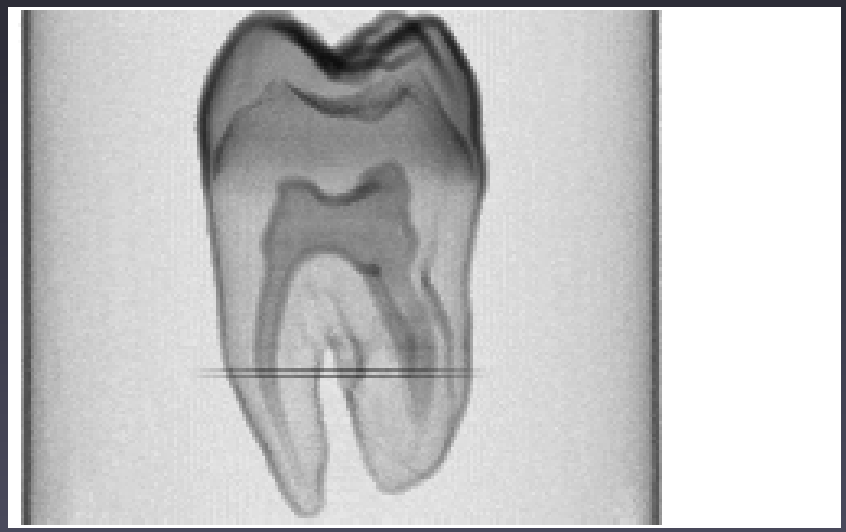
where $t_i = 1 - \alpha_i$ and $\alpha_i = |\nabla f_i| \cdot s$



# Silhouette enhancement using the “bubble model”



# Images rendered using the “bubble model”



# Advantages of the bubble model

- All the internal structures can be rendered at the same time independently from their data values
- Only one rendering parameter (linear opacity scaling)
- No visual overload - only the voxels with high gradient magnitudes contribute to the generated image

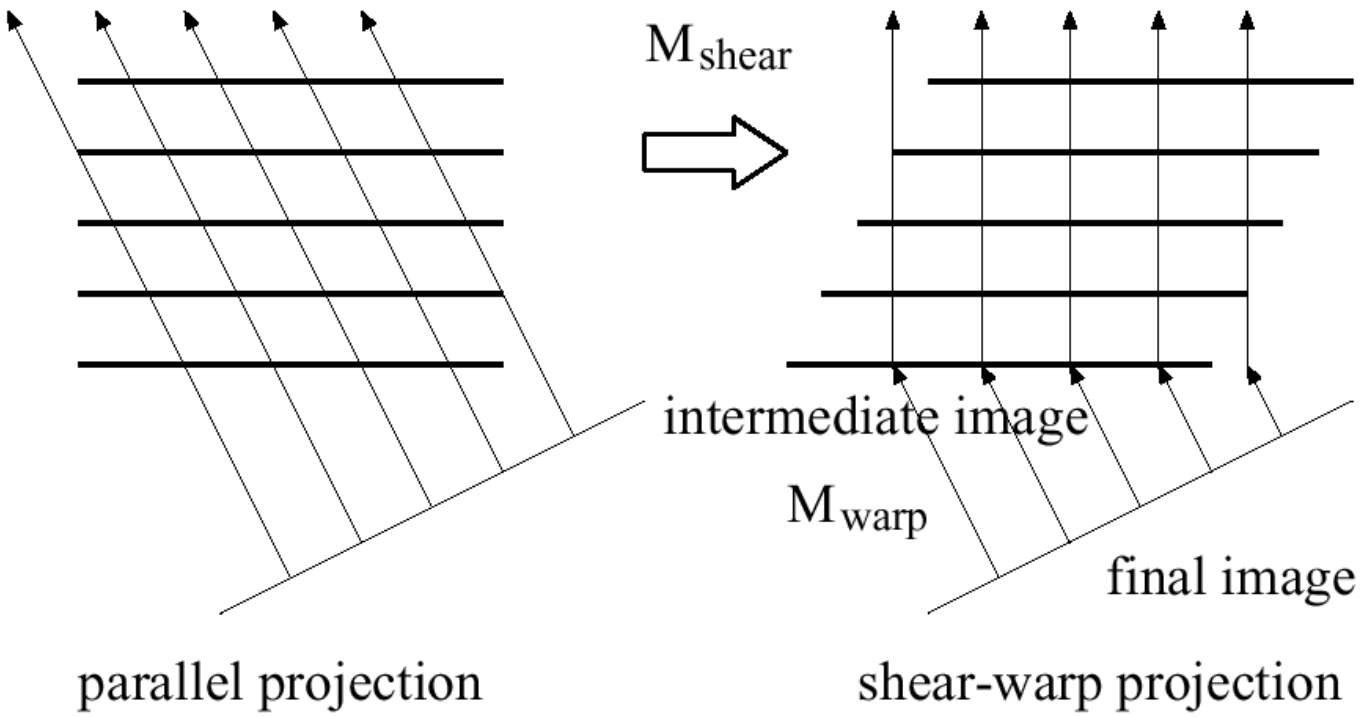
# Interactive rendering

- Extraction of surface voxels (gradient magnitudes are higher than a predefined threshold)
- Extracted voxels are projected in back to front order using a shear-warp projection
- Due to the data reduction the relevant information can be visualized interactively even on a low-end PC

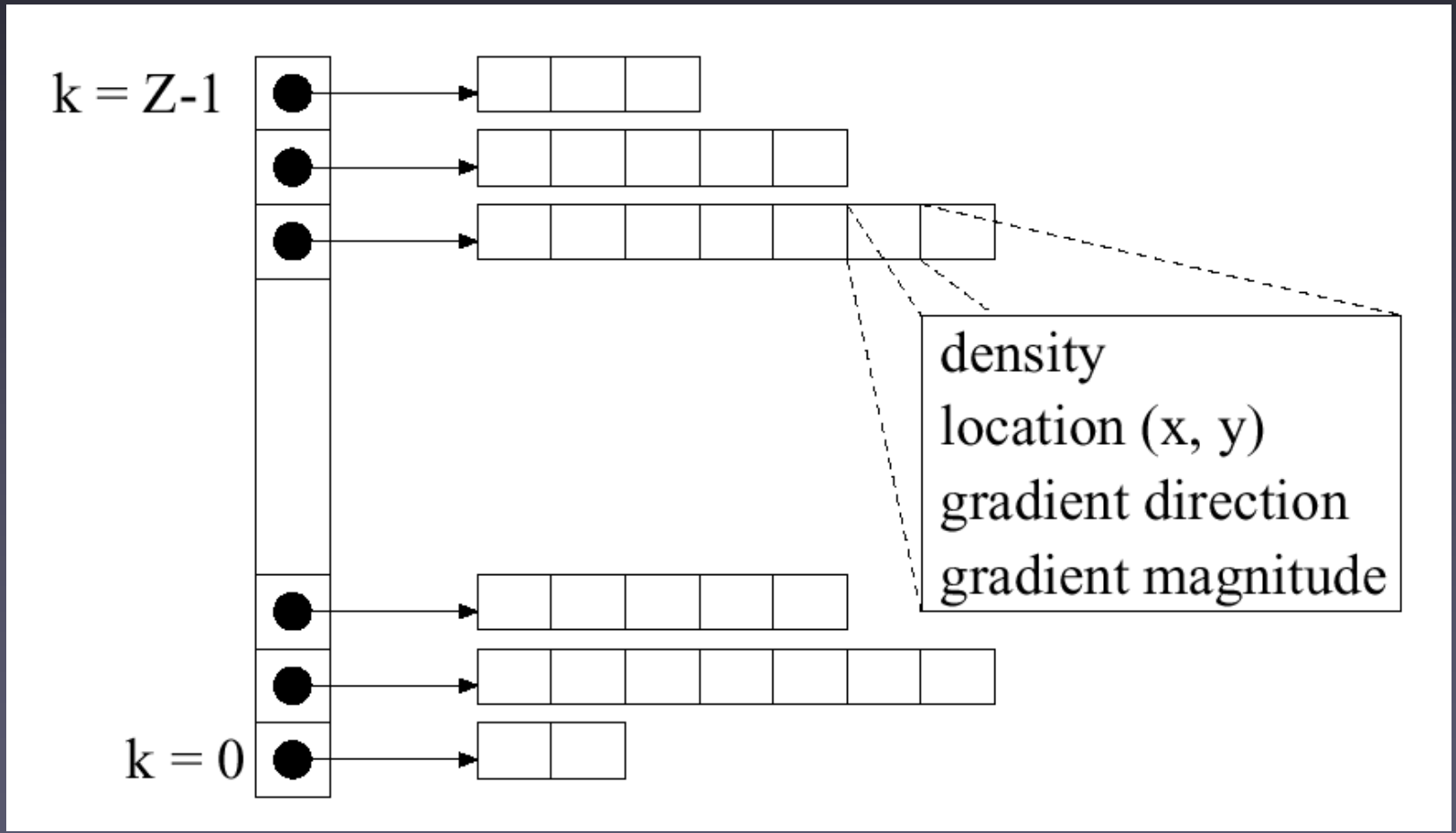


# Shear-warp projection

$$M_{view} = M_{warp} \cdot M_{shear}$$



# Bucket sort of the surface voxels

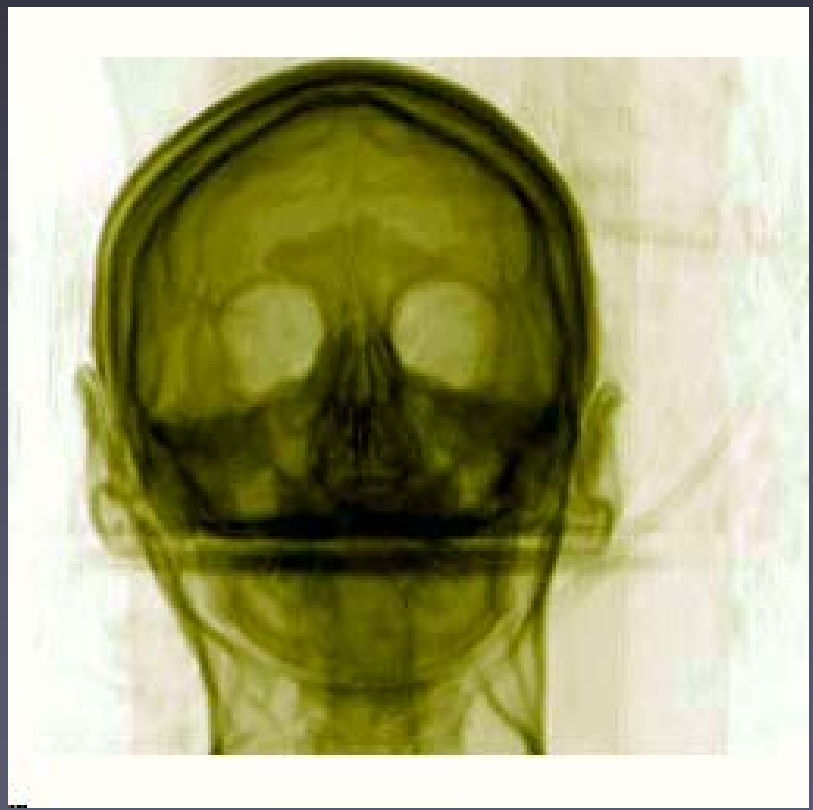


# The extended rendering model

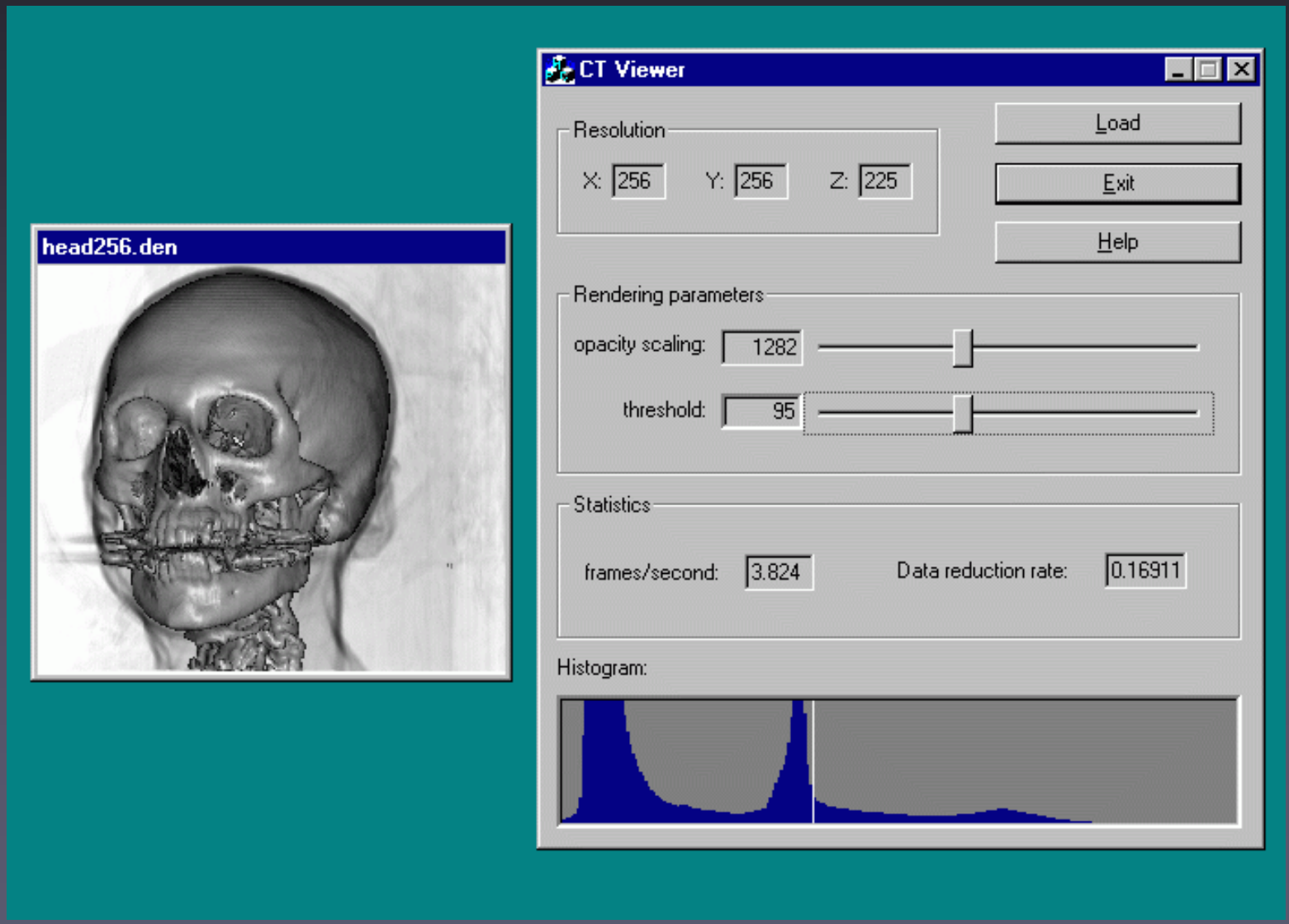
- The interactive rendering technique supports additional shaded iso-surfaces
- Real-time shading using gradient quantization  and lookup tables
- The rendering parameters (the density threshold defining the iso-surface and the opacity scaling) can be changed interactively providing an immediate visual feedback



# Volume rendering using the “bubble model”



# The user interface



# Performance

| volume | resolution | data reduction rate | frame rates |
|---|---|---|---|
| tooth | 256 × 256 × 161 | 3.48 % | 14.28 - 20.37 Hz |
| body | 202 × 152 × 255 | 16.89 % | 4.74 - 7.14 Hz |
| small head | 128 × 128 × 113 | 25.19 % | 14.08 – 20.12 Hz |
| big head | 256 × 256 × 225 | 16.91 % | 2.44 – 3.71 Hz |



# Limitations

- Trade-off between speed and image quality
- One voxel is projected onto one pixel - equivalent with nearest-neighbor resampling
- High-quality zooming is not supported
- Only parallel projection



# Conclusion

- Enhancement of the silhouettes of all the internal structures contained in the data
- Only the relevant voxels are stored and rendered
- Hardware acceleration is not required to achieve high frame rates (5-20Hz)
- No transfer function specification
- Fully interactive volume rendering (rotation and modification of the two parameters)