Bildbaserad planering av kraniomaxillofacial kirurgi med hjälp av haptik och 3D-visualisering

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Centre for Image Analysis

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IMAGE-BASED PLANNING OF CRANIOMAXILLOFACIAL SURGERY USING HAPTICS AND 3D VISUALISATION

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Röntgenveckan 2013
Uppsala 2-6 september
Tumörsjukdomar

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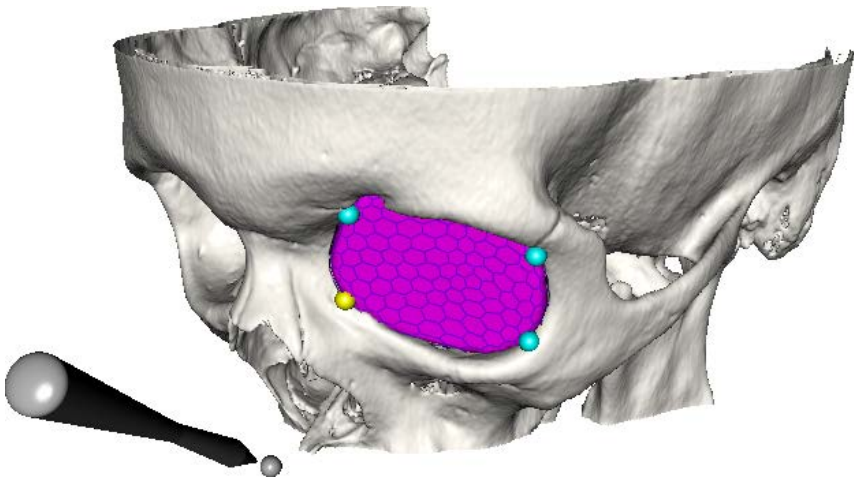
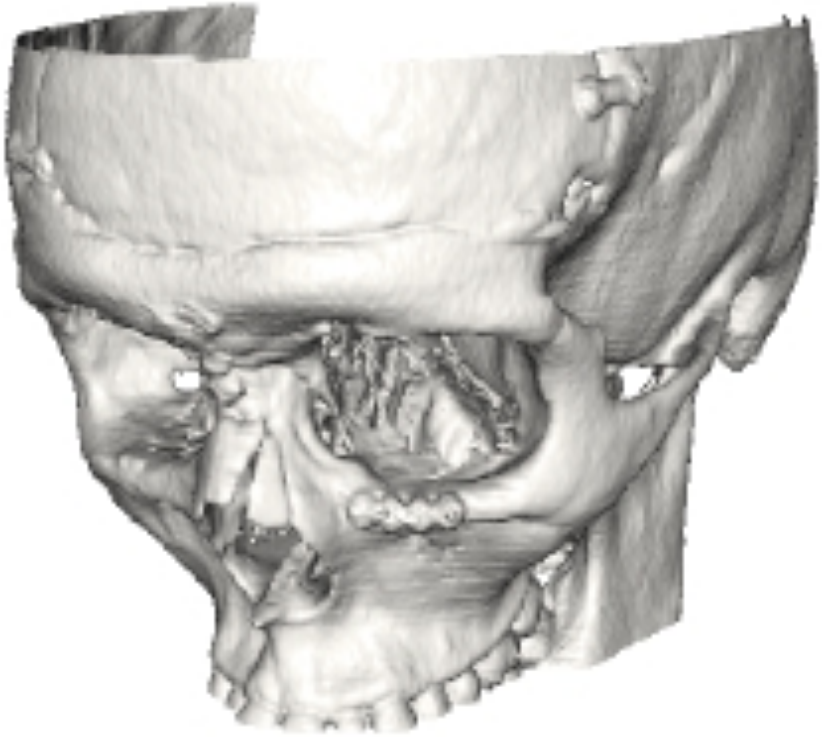


- CMF surgery
- Segmentation
- Visualization
- Haptic feedback
- Our interactive tools
- Evaluation methods

Cranio-maxillofacial (CMF) surgery planning

- A central problem in CMF surgery is to restore the normal anatomy of the facial skeleton after defects, e.g., **tumours**, malformations, and trauma to the face
- In collaboration with the Dept. of Surgical Sciences, UU



CMF surgery, continued

- There is ample evidence that careful pre-operative planning of the cranio-facial reconstruction can
  - improve the precision and predictability
  - reduce morbidity
  - reduce the time in the operating room (and thereby also cost)
- Analysis of Computed Tomography (CT) images

Segmentation

Division of an image into objects of interest and background, i.e., classification of pixels/voxels

Crucial step for the success of further image analysis

Automatic segmentation

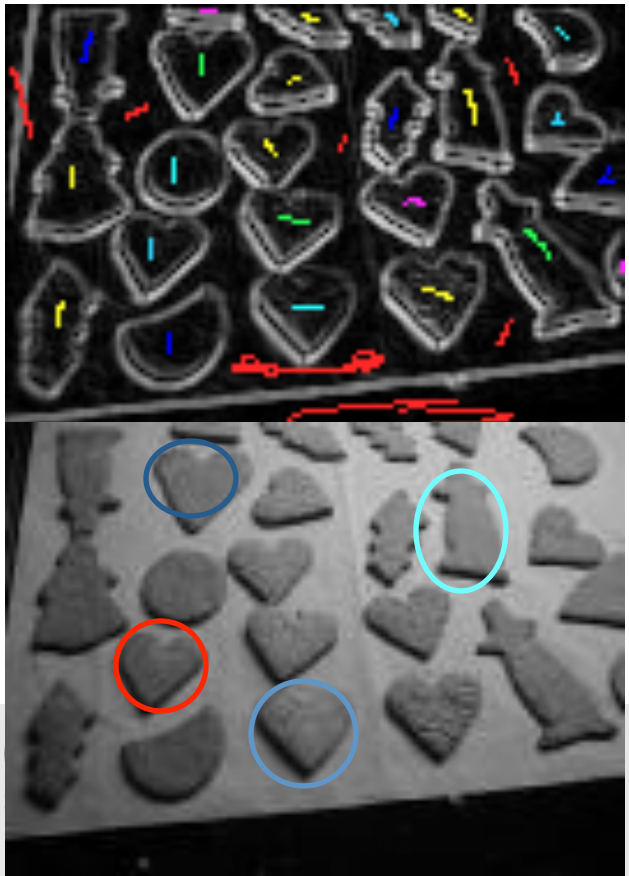
- Still seen as an open problem,
  due to that the methods cannot be general enough
- Example: simple grey-level thresholding

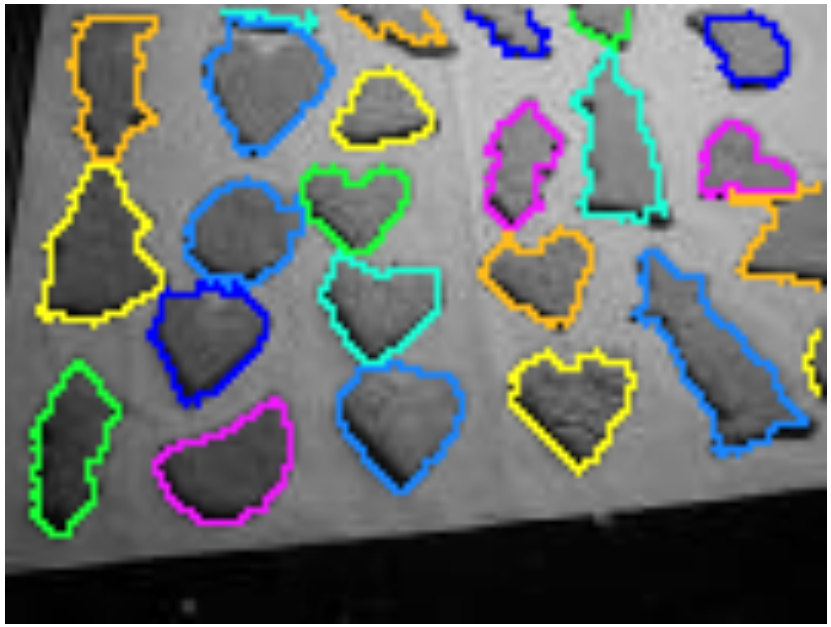
Manual segmentation

- Inter- and intra-observer variability

Semi-automatic/interactive segmentation

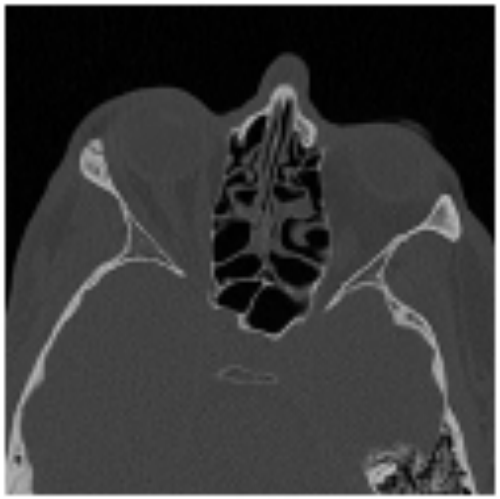
- Experts provide their knowledge by setting *seed-points* or *models*
- *Region growing* or *fitting* towards the edges

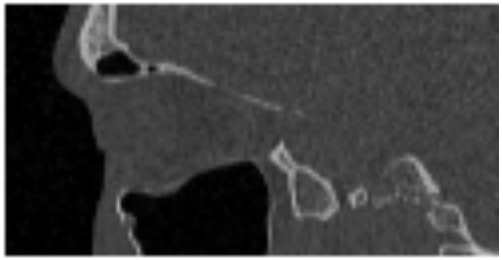




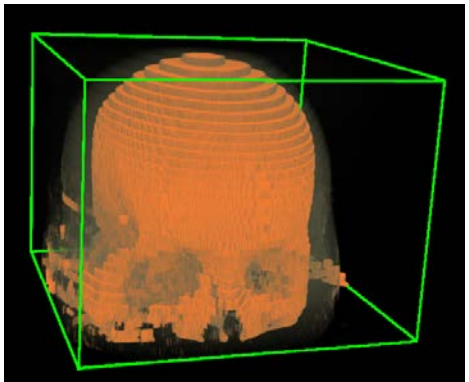
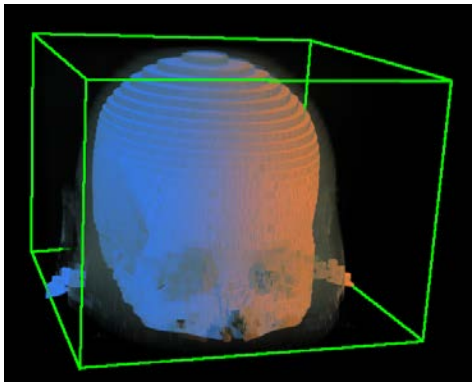
Real-time!

Orbit segmentation in CT images





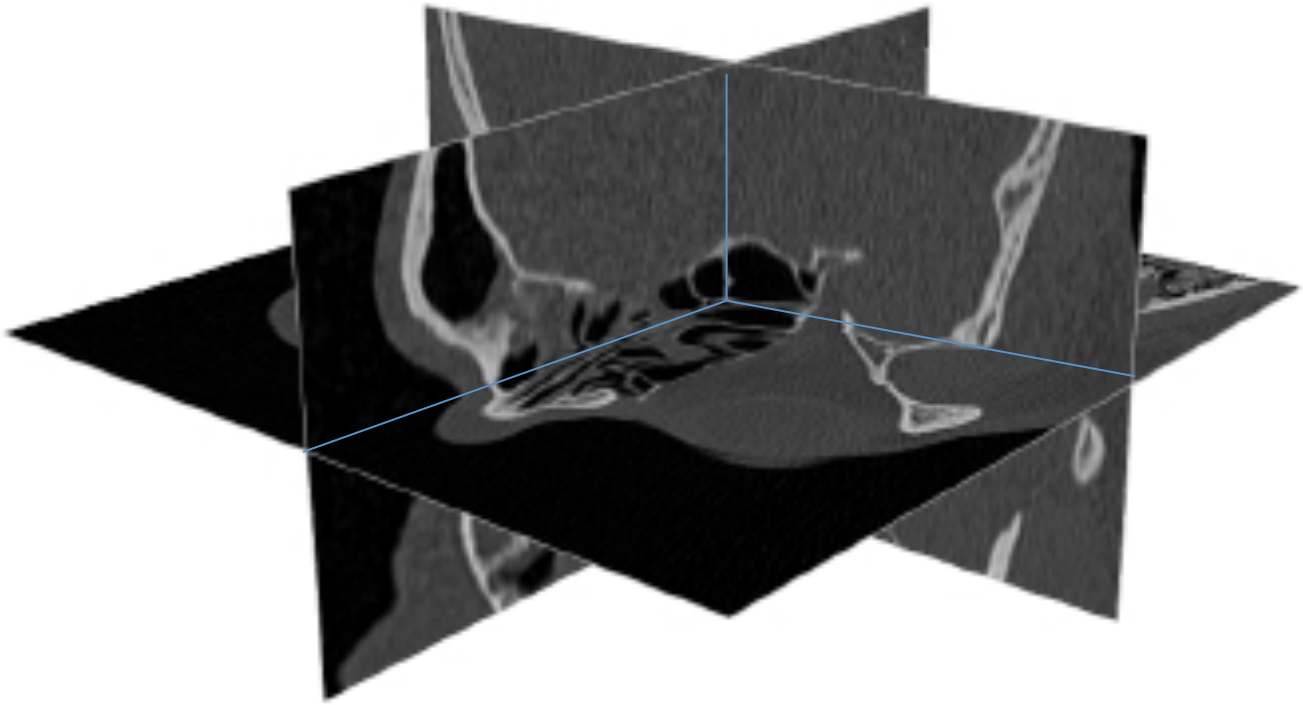
Of particular interest in CMF surgery planning is to measure the shape and volume of the orbit (eye socket), comparing an intact side with an injured side

Use multiple visualization methods

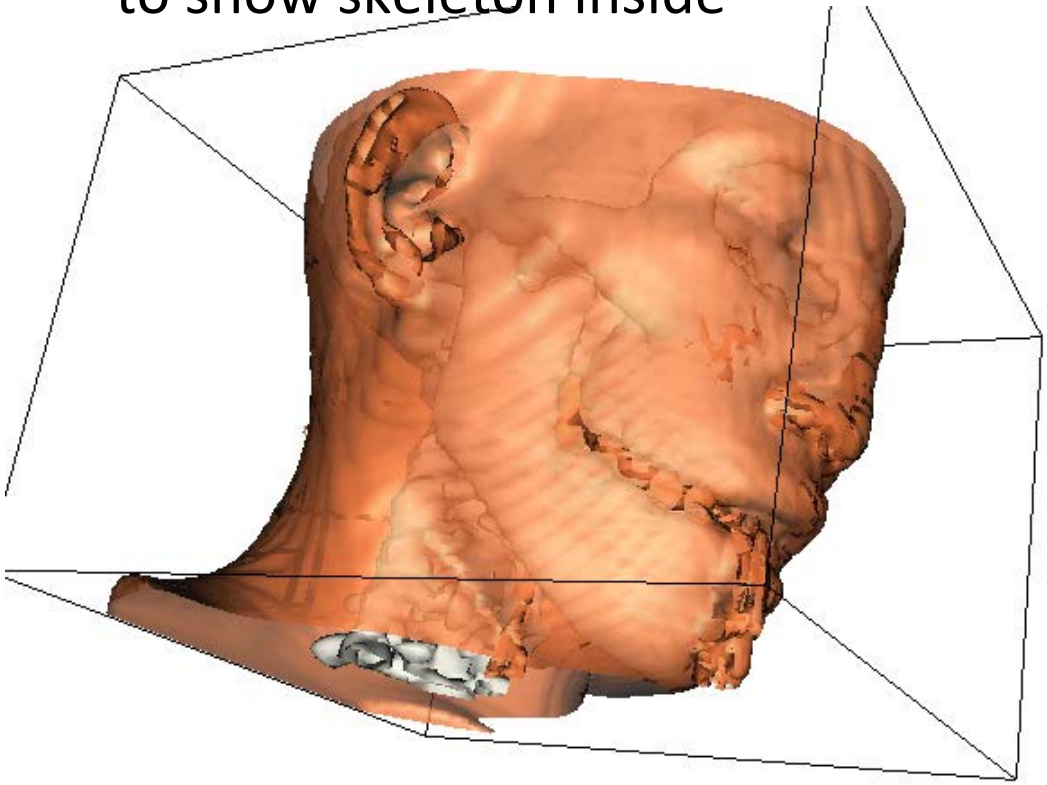
- **Maximum Intensity Projection (MIP)**
  - Simple, no segmentation required
  - Lack of depth information
  - Noise sensitive
- **Volume rendering using 3D texture mapping**
  - Interpolation accelerated in hardware (GPU)
  - Arbitrary rotations in real-time
  - Enhanced depth perception
- **Surface rendering**
  - Segmented objects
- **Multi-Planar Reformatting (MPR)**
- **Stereo rendering**
  - Further enhanced depth perception

Multi-Planar Reformatting (MPR)



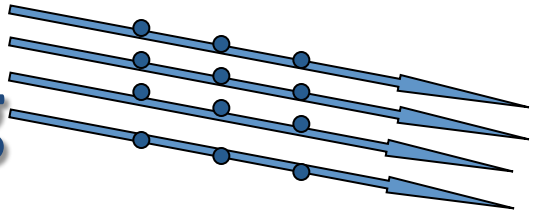
Surface Rendering

Two isosurfaces extracted in CT data where skin is shown semi-transparent to show skeleton inside

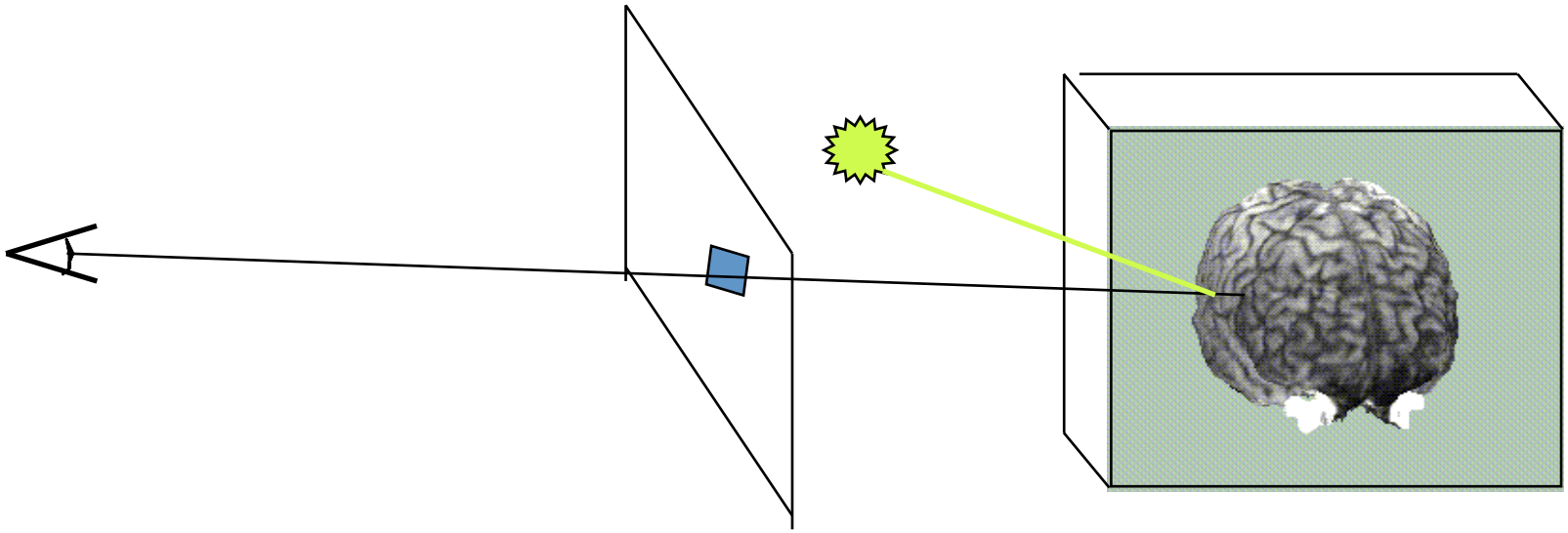


opacity
alpha value

Volume Rendering



- Ray casting is commonly used
- For each display pixel, cast one or more rays
- Calculate contribution *C* for each voxel along the ray



Stereo Rendering

Haptic Feedback

hap·tic ('hap-tik)
adj.
Of or relating to the sense of touch; tactile.
[Greek haptikos, from haptesthai,
to grasp, touch. (1890)]

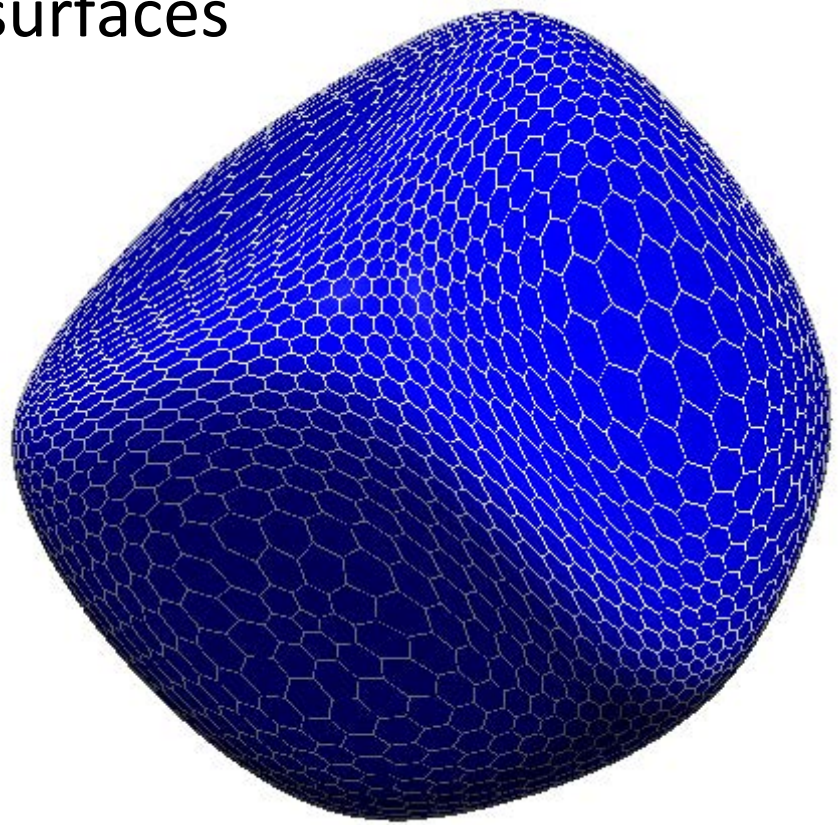
”Touch is unique among the senses because it allows simultaneous exploration and manipulation of the environment.”
[Zilles & Salisbury, 1995]

Our SenseGraphics haptics display

- **Display**
  - PHANToM haptic device
  - Semi-transparent mirror
  - Shutter glasses
  - Co-location of stereo graphics and haptics
- **Graphic update** rate: 25-30 Hz
  - to avoid flickering
- **Stereographic update** rate: 60 Hz
- **Haptic update** rate: 1 kHz
  - to avoid oscillations
  - the sense of touch is *sensitive*

Model-based segmentation

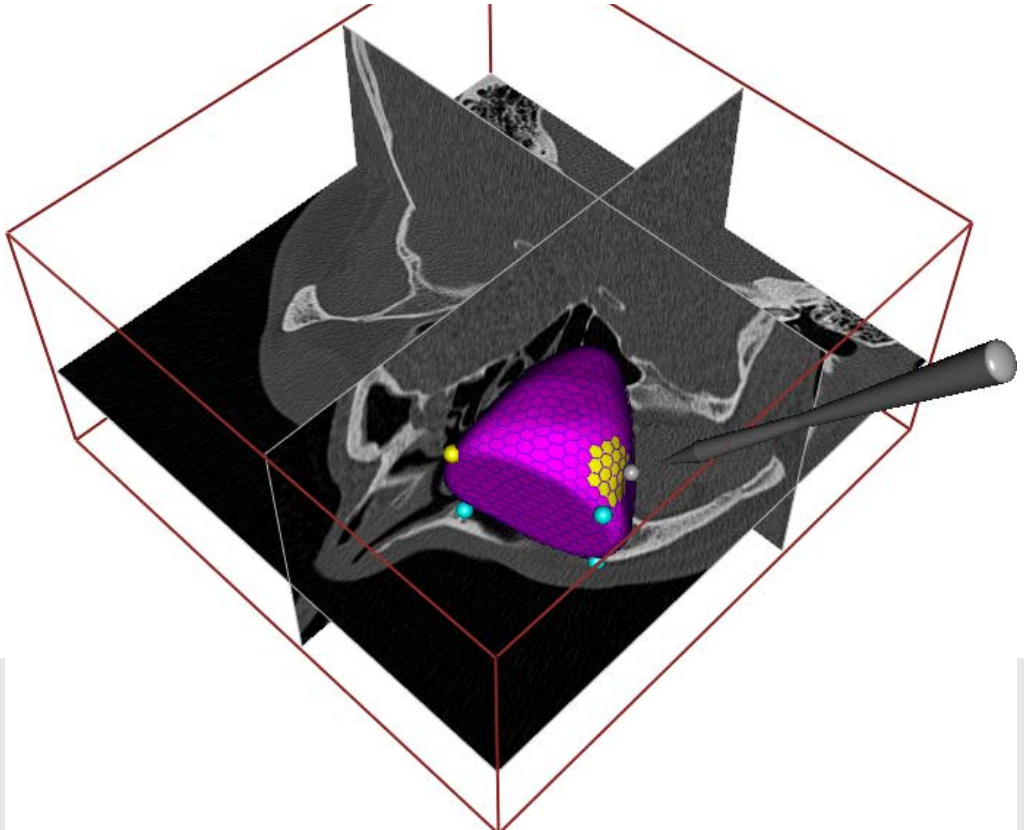
- Segmentation by deformable surfaces
- Start with an initial surface.
  Let it deform according to
  a cost function
- Haptics is used to ”drag”
  the surface to desired points



Deformable simplex mesh

The deformable simplex mesh is deformed according to Newton's second law (Newtonian evolution):

$$\mu \frac{\partial^2 \mathbf{x}}{\partial t^2} = F_{damp}(\mathbf{x}) + F_{int}(\mathbf{x}) + F_{ext}(\mathbf{x}),$$



Movie clip

Orbit Segmentation for Cranio-Maxillofacial Surgery Planning

Centre for Image Analysis, Uppsala University

Quantitative analysis: 3 evaluation factors

ac·cu·ra·cy

- The ability of a measurement to match the actual value of the quantity being measured

pre·ci·sion

- The ability of a measurement to be consistently reproduced

ef·fi·cien·cy

- The time for user interaction, training, and computation in order to have measurements

Our orbit study

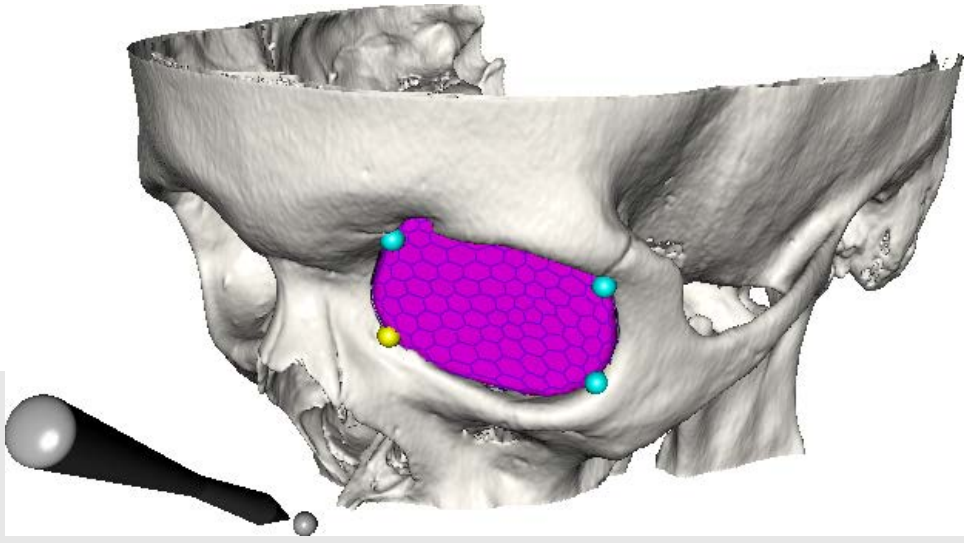
- 7 CT datasets = 14 orbits (left eye and right eye), ***twice***
- Three users performed
  - 28 manual segmentations each = ***ground truth***
    (3—37 minutes per dataset)
  - 28 interactive segmentations each
    (1—10 minutes per dataset)
- Intra-operator precision for interactive segm: 96.8 %
- Inter-operator precision for interactive segm: 95.7 %
- Inter-operator precision for manual segm: 91.3 %
- Sensitivity: appr. 99 %
- Specificity: close to 100 %

CONCLUSION: We have developed an interactive system for segmenting the orbit in CT images

- Our system utilizes a deformable simplex mesh, driven by external forces computed from the input CT image
- A 3D user interface with haptic feedback allows the user to place anatomical landmarks on the orbital rim and to guide the simplex mesh
- Preliminary results indicate that our system can be used to obtain fast and accurate orbit segmentations, with high intra- and inter-operator precision

Our system:
Interactive Medical 3D Image Analysis

- **Visualization**
  to show the volume structures
- **Haptic feedback**
  for interaction
- **Image processing and segmentation**
- **Evaluation**
  of accuracy, precision,
  and efficiency



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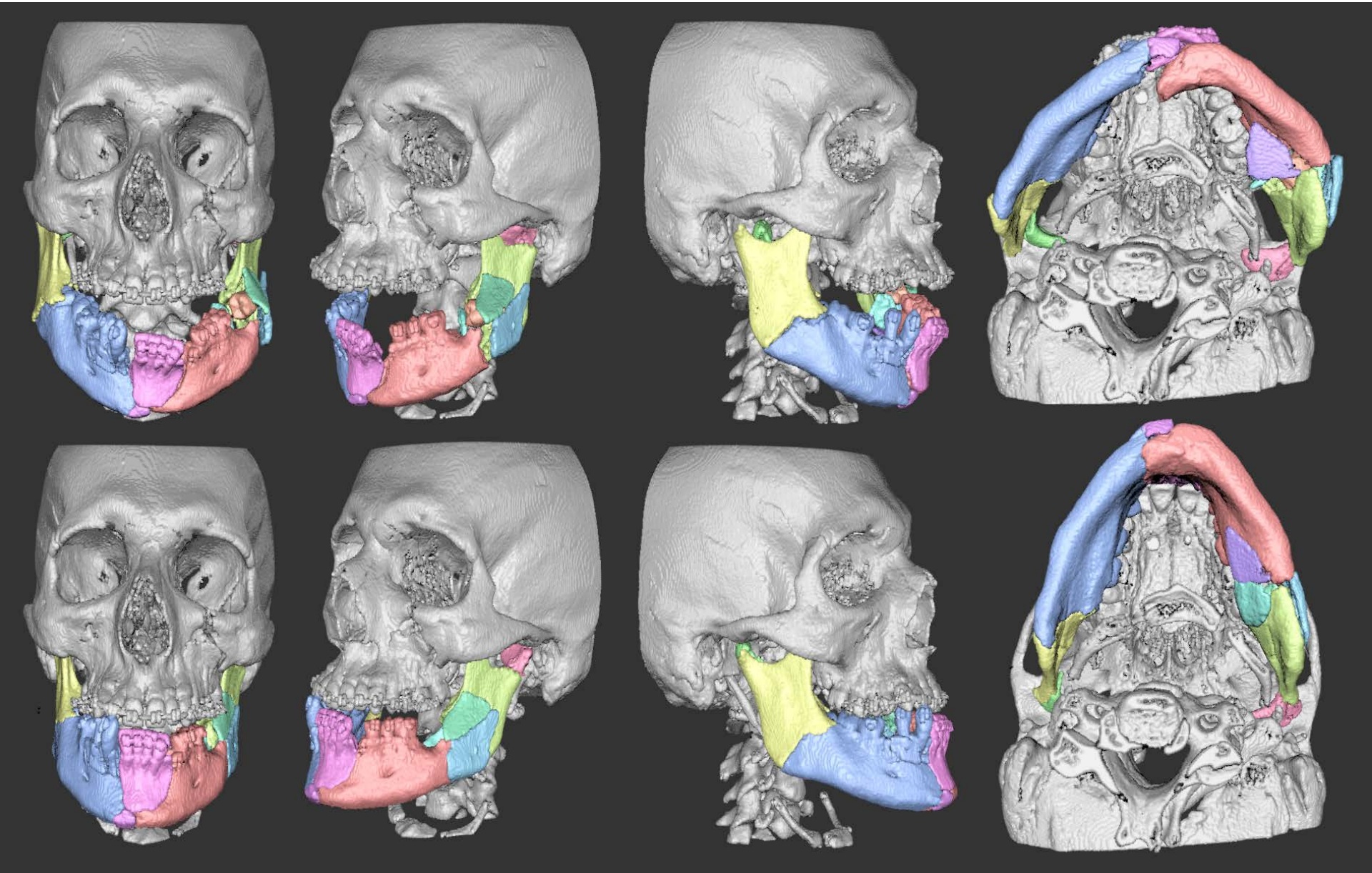
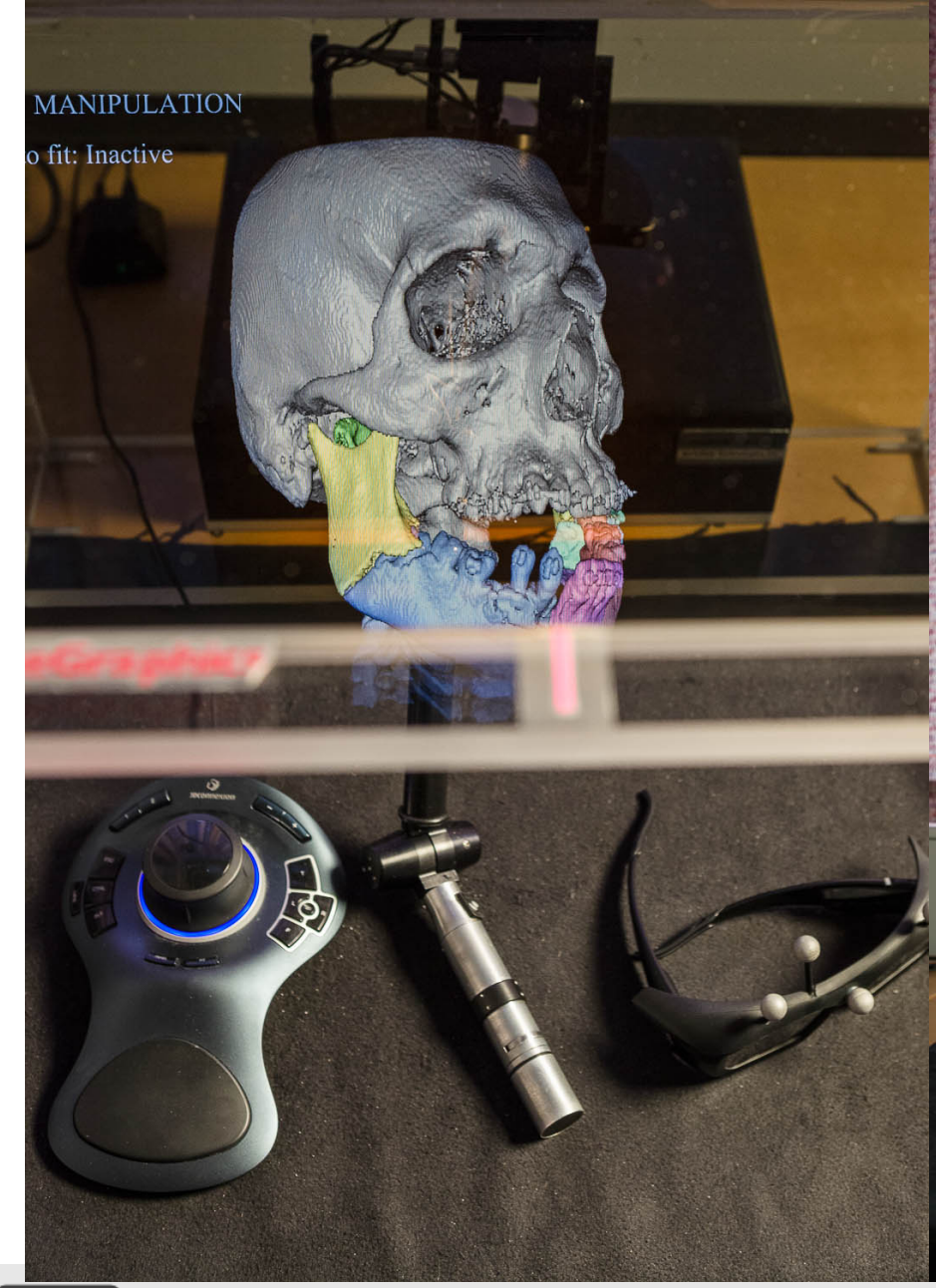
Photos by Tandläkartidningen 2013

Our current step: laying the 3D bone puzzle ”Snap-to-fit”





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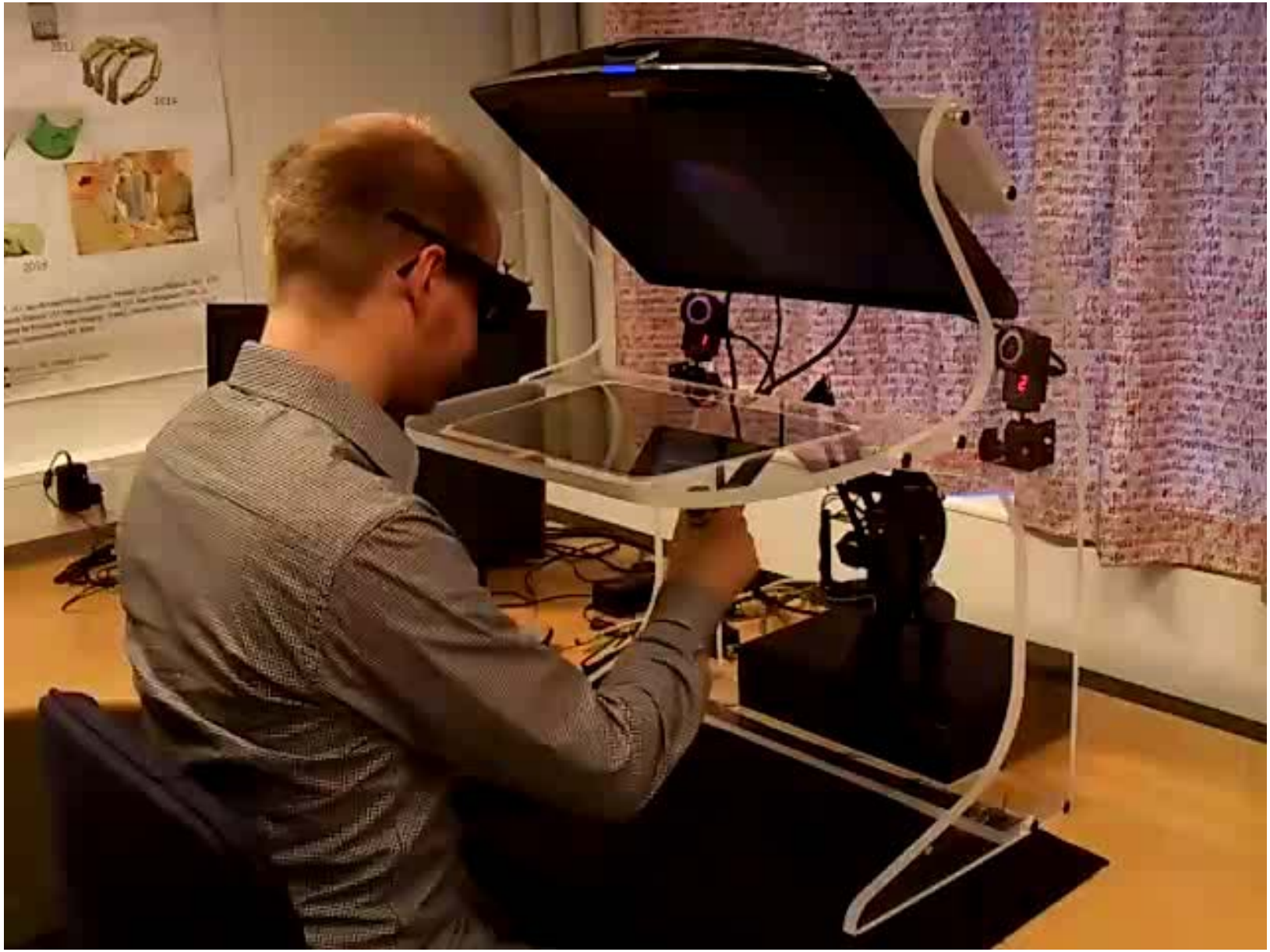

http://www.cb.uu.se/research/haptics_applications/

Acknowledgements

- **Centre for Image Analysis, UU:**
  - Ewert Bengtsson -- Ingrid Carlbom
  - Filip Malmberg -- Pontus Olsson
  - Johan Nysjö -- Fredrik Nysjö
- **Dept. of Surgical Sciences, Oral & Maxillofacial Surgery, UU:**
  - Jan Michaél Hirsch
  - Elias Messo -- Andreas Thor
- **Dept. of Craniofacial Development, King's College, UK:**
  - Roman Khonsari

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