Advanced Visual Medicine: Techniques for Visual Exploration & Analysis

Illustrative Visualization Techniques for Pre-Operative Planning

Christian Tietjen

**Visualization Research Group,
University of Magdeburg, Germany
tietjen@isg.cs.uni-magdeburg.de**

Outline

Motivation

Prerequisite: Segmentation

User Study: Liver Surgery

- Combination of Rendering Methods
- Evaluation

Case Study: Neck Dissection

- Silhouette Rendering
- Opacity Mapping
- Cutaways and Ghostviews
- Quantitative Visualization

Concluding Remarks

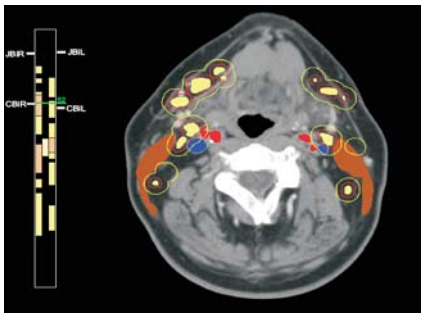
Motivation

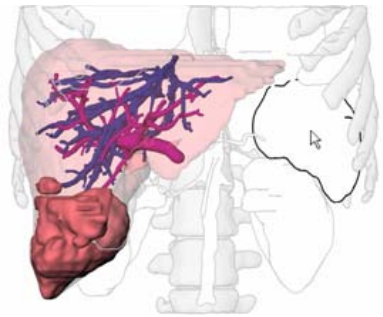
Computer assisted preoperative planning is only accomplished in cases with complex anatomy

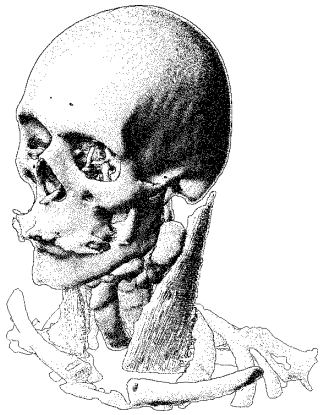
“Conventional” medical 3D-visualizations are not sufficient

Illustrative techniques are employed to generate comprehensible renderings

Traditional illustrations make extensive use of these techniques







Roland Pfisterer, Diploma Thesis, 2008

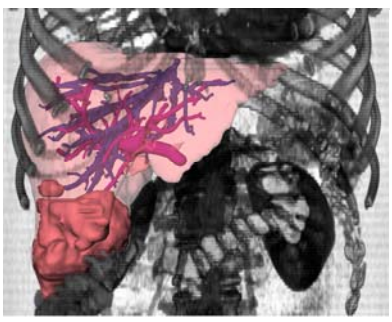
Motivation

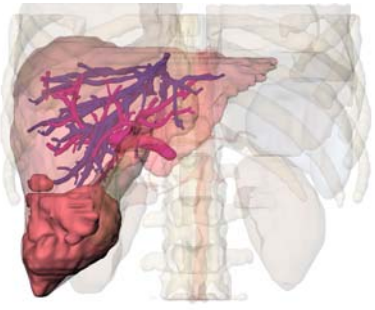
Conventional medical visualizations

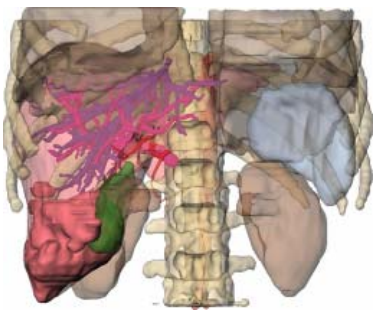
Limited degrees of freedom to emphasize structures

Context visualization hampers interpretation

- Context structures cannot be discriminated or
- Context structures hide the focus objects







Motivation

User studies indicate that:

- Hatching lines along curvature directions improve shape perception compared to surface shading

  S. Kim, H. Hagh-Shenas, V. Interrante (2004). „Conveying Shape with Texture: Experimental Investigations of Texture's Effects on Shape Categorization Judgments“, IEEE TVCG

  V. L. Interrante (1997). „Illustrating Surface Shape in Volume Data via Principal Direction-Driven 3D Line Integral Convolution“
- Silhouettes improve the ability to discriminate objects

  C. Ware, Information Visualization, Morgan Kaufman, 2001

Segmentation

Many different structures

Primarily soft tissue

- Similar intensity values
- Little gradient information

Hard to render using direct volume rendering

Automatization required

Simple methods if possible

Segmentation

Manual Segmentation
- Tumors

Threshold
- Air-filled structures

Region growing
- Bones, vessels (with contrast agent)

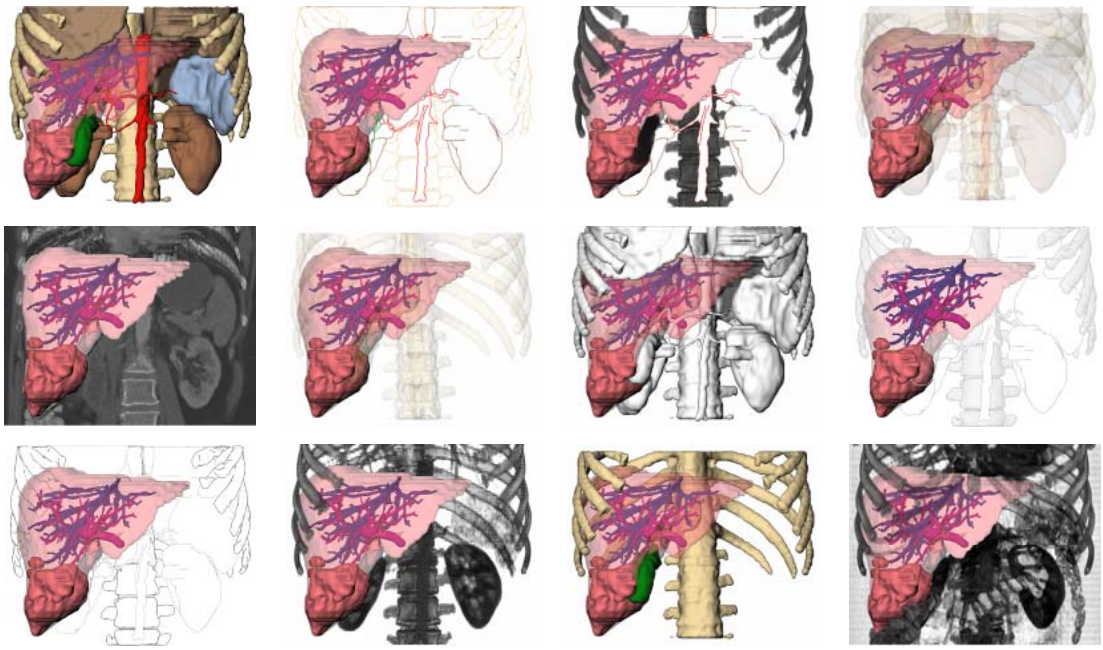
Live-Wire
- Soft tissue (muscles, vessels, glands, lymph nodes)

Spring-mass-models
- Larynx, (lymph nodes)

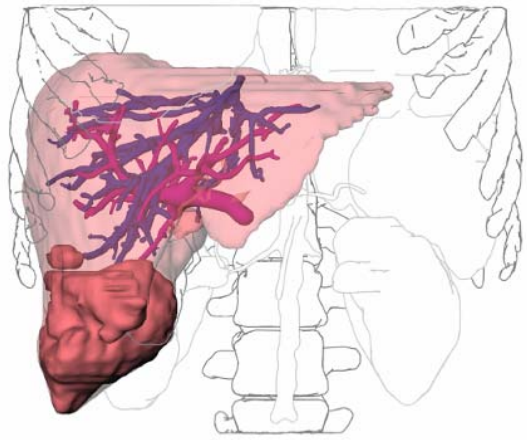
Expenditure of time for a neck dataset: 30 – 90 min

Combination of Rendering Methods

Visualization examples



Evaluation



Which rendering suits more at first glance?

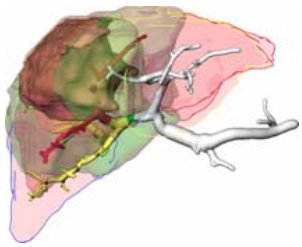
Some critical questions to both renderings

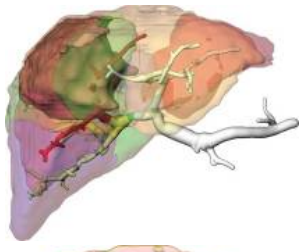
Which rendering would be more appropriate for surgical planning?

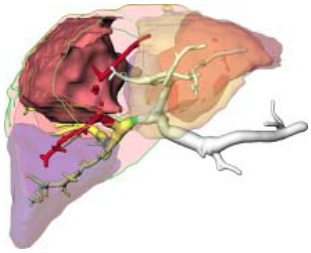
Evaluations

Is the application of illustrative techniques suitable for medical visualization?

- Informal user study (11 surgeons)
- Context visualization
- Simplifying complex visualizations

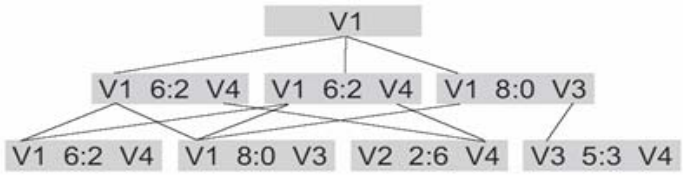






Analysis by decision tree

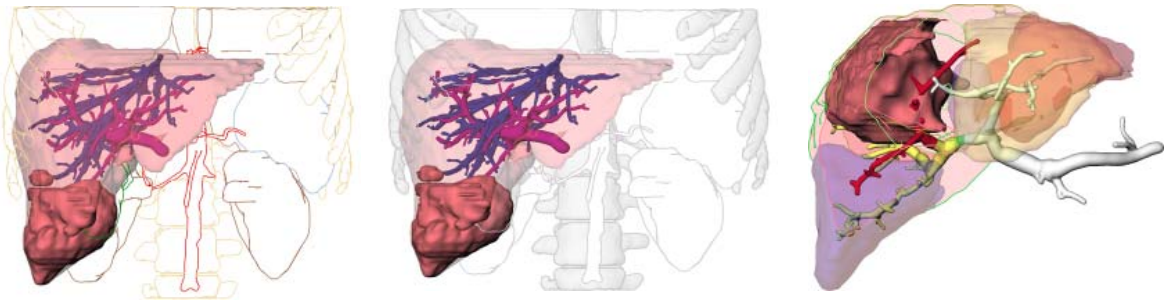
- Reference image was compared with all other images
- Number of votes was counted



Evaluations

Interpretation

- In general less context information is preferred
- Basic information about all objects is necessary
- b/w-silhouettes are not sufficient for displaying context
- Emphasize affected vascular territories using silhouettes regarded as appropriate by six of eight surgeons



Case Study: Neck Dissection Planning

Outline:

Medical Background

Questions and goals of surgeons

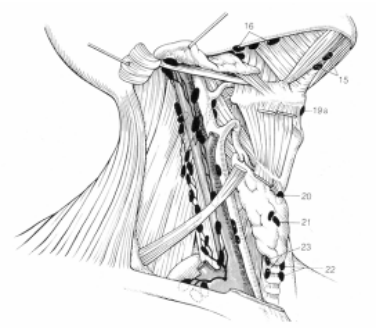
Visualization (conventional and illustrative techniques)

Quantitative Visualization

Background for Neck Dissections

Indication: Patients with malignant tumors in the neck region

- Lymph nodes will be precautionary resected
- Operation strategy respectively radicalism depend on number, position and size of lymph nodes
- Computer assisted preoperative planning can help to choose a gentle operation strategy



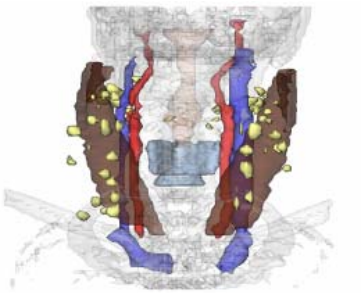
Lymph channels

Naumann H.H., Kopf und Hals-Chirurgie, Vol. 3: Hals (OP-Atlas), 2nd ed., Thieme, 1998

Neck Dissections: Visualization

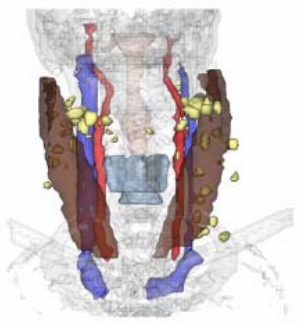
High density of anatomic structures

- Muscles, vessels, glands, bones, nerves, respiratory tract, tumor etc.
- Up to 60 lymph nodes
- Spatial assignment and correct depth perception are difficult



Questions and goals of surgeons:

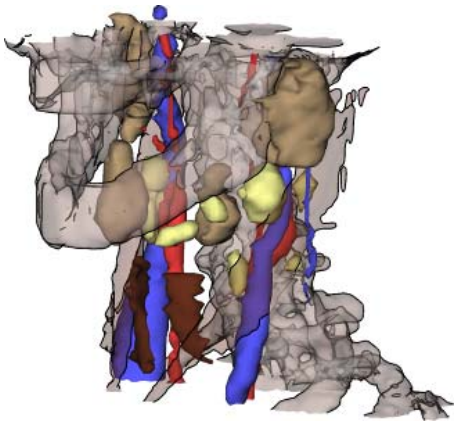
- Existence and location of enlarged lymph nodes?
- What are the distances to structures at risk?



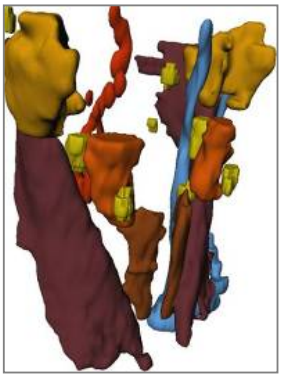
Neck Dissections: Visualization

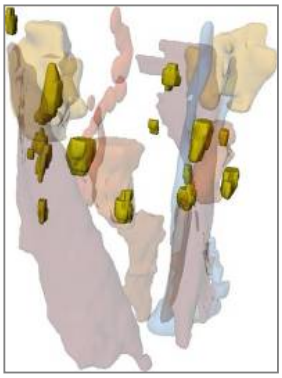
Silhouettes for edge enhancement

- Silhouettes for context objects (skeletal structures, large muscles, …)
- Cubic interpolation between the original slices for smoother surfaces

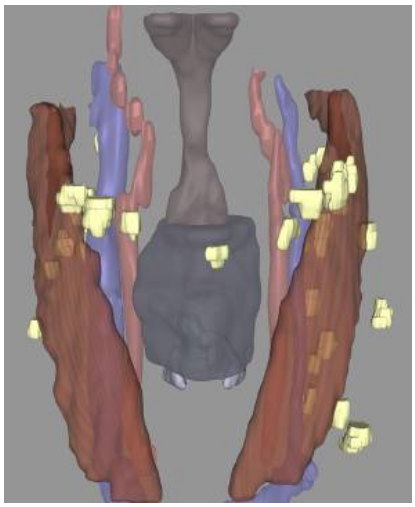


Neck Dissections: Color and Material





Correlation between transparency and spatial understanding



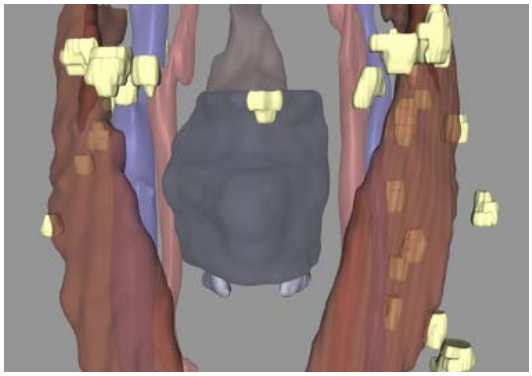
Opacity mapping applied to muscles

Context structures: slightly saturated colors

Shininess applied to vessels

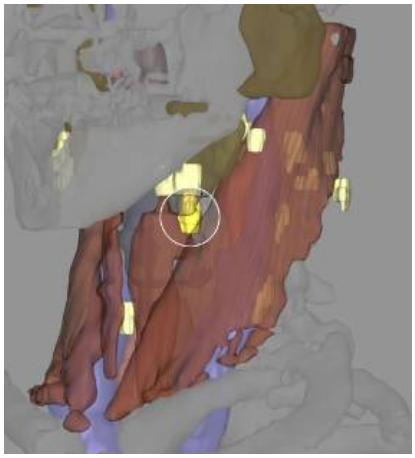
Neck Dissections: Color and Material

Opacity Mapping:



Neck Dissections: Lymph Nodes Exploration

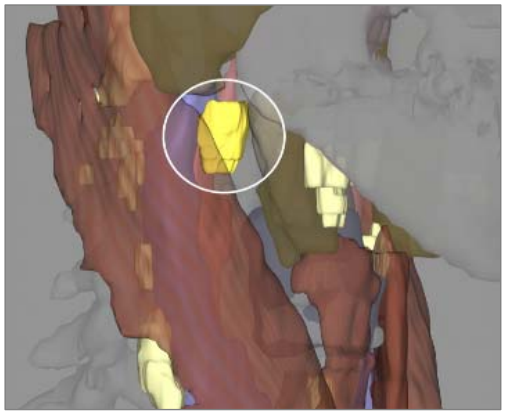
- Ghostviews for the sequential emphasis of lymph nodes
- Cylindrical cutting volume, color saturation, transparency and silhouettes



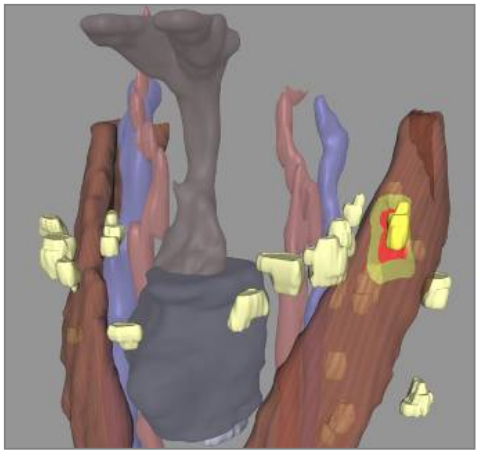
Neck Dissections: Ghost Views and Silhouettes

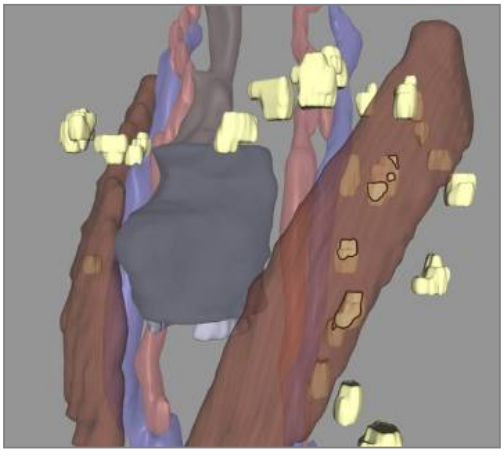
Geometry reduction for interactive cutaways and ghostviews:

- lymph node model *L* circa 10K to 100K vertices
- Convex hull *CH(L)* in 3d → ~200 vertices (viewpoint independent)
- Project CH(L) to the viewplane
- CH(P(CH(L))) in 2d → ~20 vertices
- Minimal enclosing circle + margin to define a cylindrical cutregion
- Draw silhouettes on edges



Neck Dissections: Quantitative Visualization





Left: Color coded distance between muscle and lymph node, calculated on volume data (Euclidean DTF)

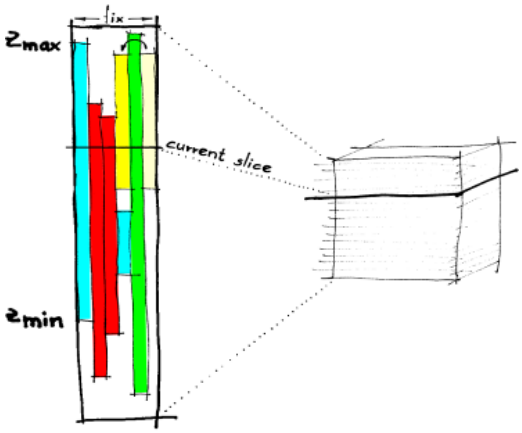
Right: Possible infiltration of the muscle by the lymph nodes, drawing of silhouette lines on intersections

Visualization Techniques: LiftChart

- Providing a faster overview
- Giving hints for critical points
- Where are interesting slices and where not?

LiftChart:

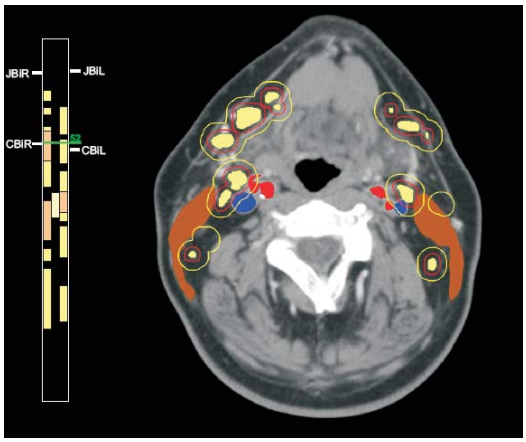
- A narrow frame next to the cross sectional image
- The frame represents the overall extent of the dataset
- Each segmented structure is displayed as a bar
- The vertical extent of the bar represents the extent of the structure

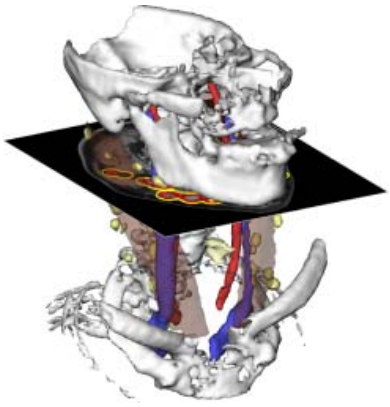


Visualization for Neck Dissections

Intervention planning:

- LiftChart for providing the overview
- Only lymph nodes and tumor are shown
- Lymph nodes are aggregated by side and colored by size
- Safety margins are showing possible infiltrations



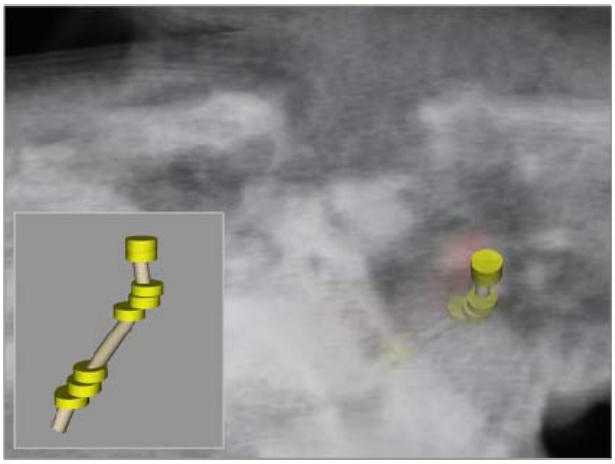


Neck Dissections: Approximative Visualization

- Small structures can only be partially segmented due to the partial volume effect.
- Approximative visualizations are helpful provided that the uncertainty is encoded.

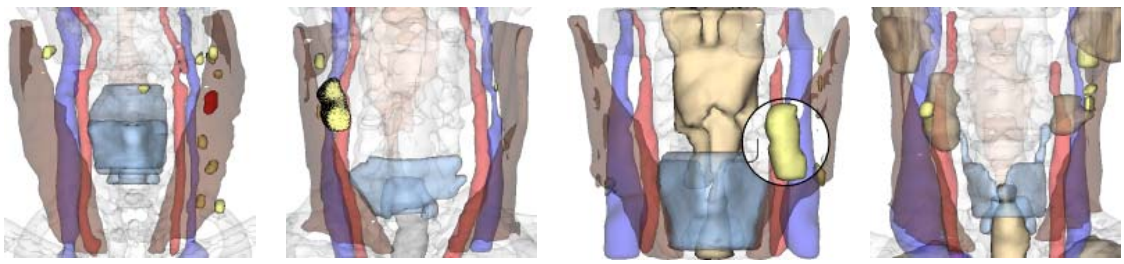
Example:
Nerves are detected in a few slices. Corresponding positions are marked with disks and connected with straight lines.

Surgeons interpret these images using anatomic knowledge.



Evaluations

- Perception speed is enhanced by illustrative techniques?
- Simple response time tests
- 3D-renderings of 14 different neck datasets (600 images)
- Only one enlarged lymph node
- Task: identify the side containing the enlarged lymph node as fast as possible



Red Stippling Cutaway Normal

Evaluations

- Interactive 3D-visualization in ENT-surgery is reasonable? (Fischer et al. 2008)
- Results after presentation of the 3D-reconstruction
- Change of strategy: 2/7
- Change of Assessment of fatal risk structures: 4/7
  - 2x infiltration of MSCM,
  - 1x infiltration of thyroid cartilage,
  - 1x no infiltration of thyroid cartilage and glottic area
- Level-of-Trust:
  - 3D-Visualization beneficial 7/7
  - Average LOT 68
- TNM-classification:
  - 7/7 same classification by NSP compared with pTNM

Concluding Remarks

Illustrative techniques cannot replace but enhance conventional rendering techniques

Visualization for surgery planning:

- Standardized visualizations for surgical planning (time savings, reproducibility)
- Include quantitative information in visualizations
- Adjust material properties and silhouettes for focus control and enhanced spatial recognition
- Sequential emphasis of pathologic structures (lymph nodes, lung nodules, …) using ghostviews

Concluding Remarks (cont`d)

User studies are required to compare visualization options with respect to task-specific problems (e.g. exploration of vasculature around a tumor).

Investigate usefulness:

- Does your (new) visualization technique provides additional insight?
- Influence surgical strategies?

Thank you for your Attention!

Christian Tietjen
tietjen@isg.cs.uni-magdeburg.de

Department of Simulation and Graphics
Faculty of Computer Science, University of Magdeburg, Germany
Visualization Group
http://wwwisg.cs.uni-magdeburg.de/cv/

MeVis Research
Center for Medical Image Computing
Bremen, Germany
http://www.mevis.de

ENT Department
University Hospital of Leipzig, Germany
Innovation Center for Computer Assisted Surgery
http://www.iccas.de

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