Computer-Integrated Surgery II

Seminar Presentation

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Statement of my project – HMD in orthopedic surgery

- Background
  - Orthopedic surgery requires placements of screws and wires into bones
  - Current 2D imaging guidance system could be confusing and requires lots of X-ray doses
  - Augmented Reality can help!

- Goal
  - Deploying HMDs with simple 2D X-ray views to orthopedic surgery
  - Use augmented reality to visualize the occluded part of the needle
  - Comparison of user's perception of AR visualizations

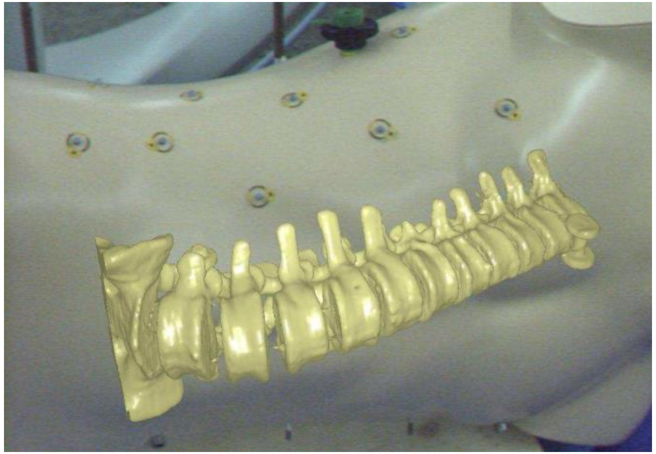
Paper Selections

- C. Bichlmeier, F. Wimmer, S.M. Heining, N. Navab
  Contextual Anatomic Mimesis: Hybrid In-Situ Visualization Method for Improving Multi-Sensory Depth Perception in Medical Augmented Reality
  The Sixth IEEE and ACM International Symposium on Mixed and Augmented Reality, Nara, Japan, Nov. 13 - 16, 2007.

- C. Bichlmeier, M. Rustaee, S.M. Heining, N. Navab
  Virtually Extended Surgical Drilling Device: Virtual Mirror for Navigated Spine Surgery
  Proceedings of Medical Image Computing and Computer-Assisted Intervention (MICCAI 2007), Brisbane, Australia, October/November 2007.

Hybrid In-Situ Visualization Method for Improving Multi-Sensory Depth Perception in Medical Augmented Reality

- Why do I choose this paper?
  - The paper focuses on solving the misleading perception of depth and spatial layout problem in medical Augmented Reality
  - Though the paper is about video see-through, the visualization clues (transparency, etc.) are useful
- Why this is important?



Summary of problem & Key result

- Problem Summary
  - Misleading perception of depth
  - Misleading spatial layout

- Key Result
  - Presents a new method for medical in-situ visualization

- Significance
  - The new method allows for improved perception of 3D medical data
  - Helps navigate surgical instruments relative to the patient’s anatomy

Background

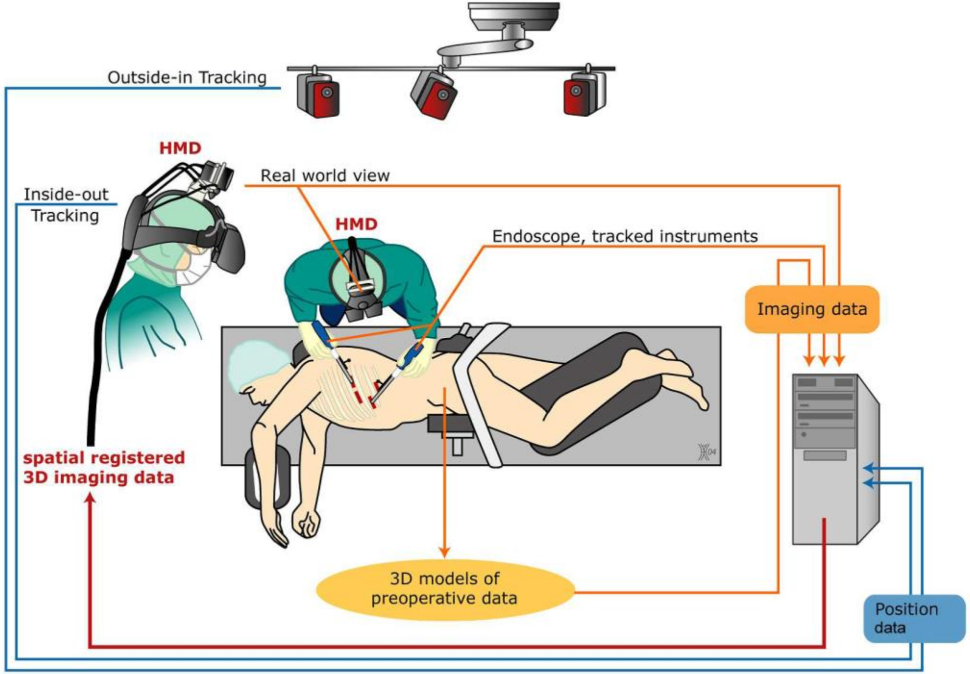
- Being able to see into a living human system largely improves medical diagnosis and reduces invasive surgeries
- Various approaches – CT, MRI, Ultrasound
- Milestone approaches by other people:
  - Bruckner – context preserving volume rendering model [1]
  - Krueger – ClearView method [2]

[1] S. Bruckner, S. Grimm, and A. Kanitsar. Illustrative context preserving exploration of volume data. *IEEE Transactions on Visualization and Computer Graphics*, 12(6):1559–1569, 2006. Member-M. Eduard Groller.

[2] J. Krueger, J. Schneider, and R. Westermann. Clearview: An interactive context preserving hotspot visualization technique. *IEEE Transactions on Visualization and Computer Graphics*, 12(5):941–948, 2006.

Description of author's work – Part 1

- System set-up



Every target should positioned with respect to the reference frame of the inside-out tracking system.

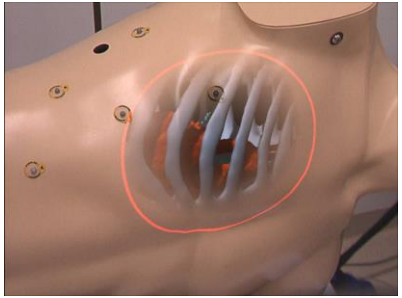
$$^{target}T_{ref} = {}^{target}T_{ext} \cdot ({}^{ref}T_{ext})^{-1}$$

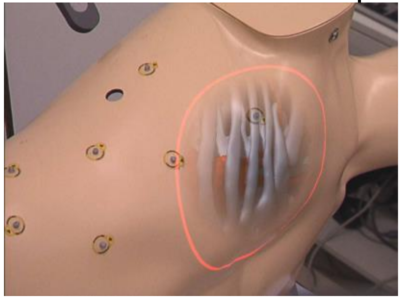
Transformation from ref to CT

$$^{CT}T_{ref} = {}^{CT}T \cdot {}^{patient}T_{ext} \cdot \left({}^{ref}T_{ext}\right)^{-1}$$

Description of author's work – Part 2

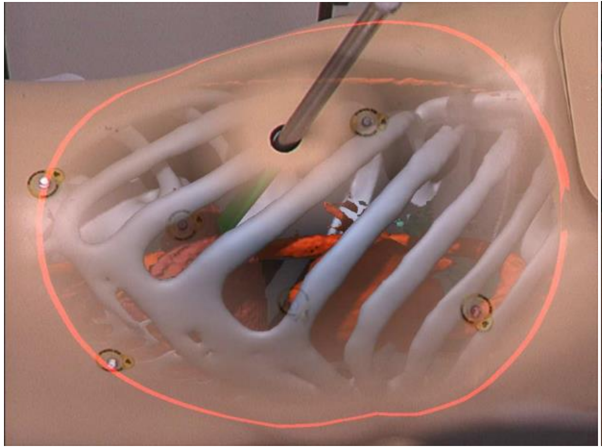
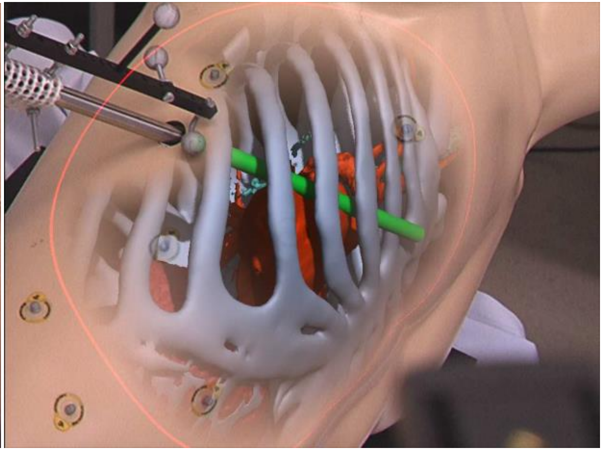
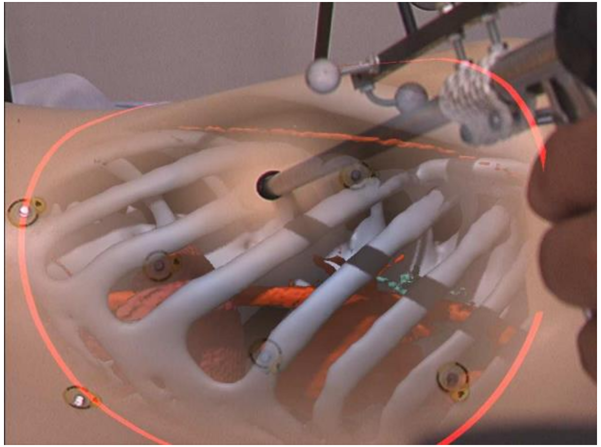
- Divide the skin into two domains
  - Transparent and semi-transparent within the vision (TransDom)
  - Opaque skin outside the vision channel (OpaDom)
- How to divide into these two domains?
  - The curvature within the region around a fragment on the skin surface
  - The angle between the fragment normal and the vector from the position of the fragment to HMD
  - The distance of a fragment on the skin surface to the intersection point of the line of sight with skin
- Transparent vs Semi-transparent
  - Red line based on the distance of a fragment to the intersection point of the line of sight





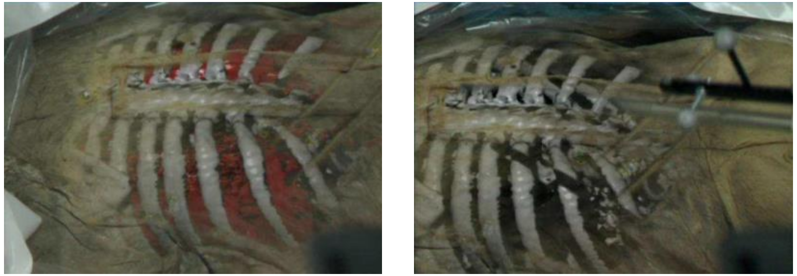
Description of author’s work – Part 3

- Integration of Surgical Instrument
  - Stencil bit is set for fragments of instrument that are laying under the skin surface
  - A shadow mapping algorithm was integrated to provide better visual feedback

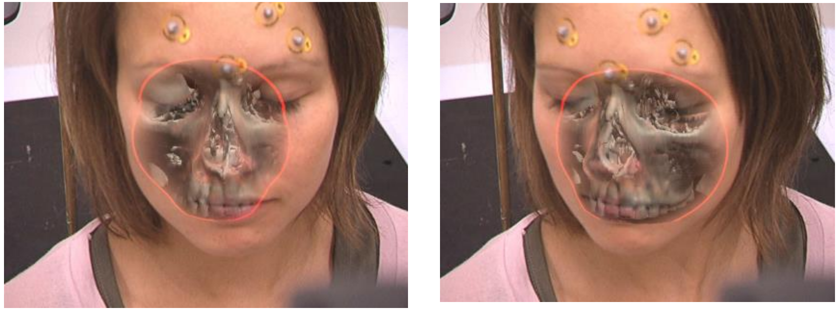




Results

- Cadaver Study



- Phantom Study – result graphs are in the previous slides
- In-vivo Study



Discussion

- Pros
  - Implemented surface detection for better instrument visualization
  - Provides many ways of rendering and virtual cues – transparency, shadow, color
  - Similar to the visualization I will be working on

- Cons
  - It is video see-through augmented reality
  - Surface models have to be segmented, triangulated and smoothed before the visualization

- Possible next steps
  - Render CT/MRI data in real-time without preparative steps
  - Deeper visualization for regions hidden by bones and tissues
  - More effects about textures, ridges and valley lines on visualizations

Conclusions

- A great approach to modify the transparency of video images recoded by a video see-through head-mounted display
- Different viewing geometry of the observer and skin surface produces different transparency effects
- Describe a method for integrating surgical tools to improve navigation in medical augmented reality

Virtual Extended Surgical Drilling Device: Virtual Mirror for Navigated Spine Surgery

- Why do I choose this paper?
  - This paper introduces a new method for navigated spine surgery using a stereoscopic video see-through head-mounted display (HMD) and an optical tracking system
  - The visualization can be directly registered with the real operation site for diagnoses, surgical planning, and intraoperative navigation

Summary of problem & Key result

- Problem Summary
  - A point of view on the operation site, for example, from beneath the operation table, is impossible
- Key Result
  - The virtual mirror assists to enable intuitively the desired perspectives
- Significance
  - A new method in the imaging guidance system filed that implements augmented reality to navigate spine surgery

Background

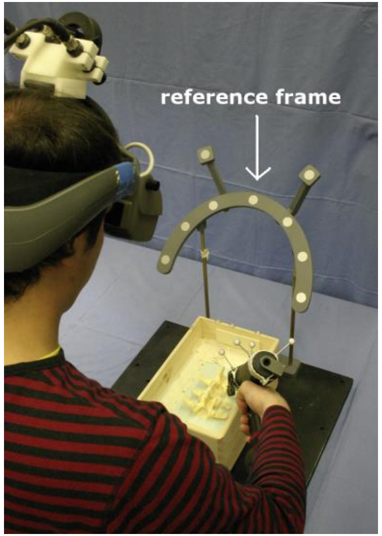
- AR for intra-operative visualization and navigation has been a popular topic
- Milestone approaches by other people:
  - Azar – presented a user performance analysis and showed that HMD is better in avoiding surrounding structures and faster in completing the task [1]
  - Navab – introduced the laparoscopic virtual mirror for liver resection [2]

[1] Azar, F.S., Perrin, N., Khamene, A., Vogt, S., Sauer, F.: User performance analysis of different image-based navigation systems for needle placement procedures. Proceedings of SPIE. 5367, 110–121 (2004)

[2] Navab, N., Feuerstein, M., Bichlmeier, C.: Laparoscopic virtual mirror - new interaction paradigm for monitor based augmented reality. In: Virtual Reality, Charlotte, North Carolina, USA, March 2007, pp. 43–50 (2007)

Description of author’s work – Part 1

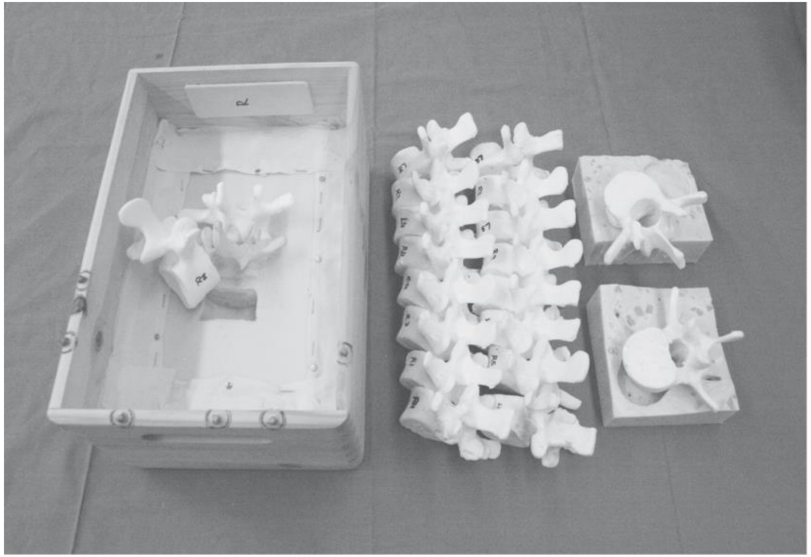
- AR System – Similar to the set up in the previous paper
  - Two synchronized tracking systems
    - Single inside-out tracking system that tracks the HMD with high rotation precision
    - Optical outside-in tracking system covers a large working area
    - Both systems used fiducial markers, attached to the drill and phantom



$$^{CT}H_{ref} = {}^{CT}H_{phantom} \cdot {}^{phantom}H_{ext} \cdot ({}^{ref}H_{ext})^{-1}$$

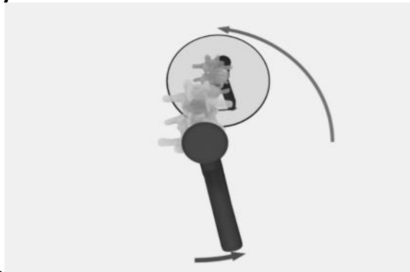
Description of author's work – Part 2

- Phantom
  - Consisting of three vertebrae embedded in a silicone mold
  - The outer two are replaceable
  - Filled with peas to simulate the restricted view like in the real surgical scenario



Description of author’s work – Part 3

- Integration of the Virtual Mirror
  - Polygonal surface model of the vertebrae, a red arrow, the virtual mirror, a blue cylinder
- Planning
  - Red arrow is orientated to the drill direction and positioned at its tip
  - The virtual mirror is used to provide side views of the semi-transparent vertebrae



- Drilling
  - When planning is finished, the mirror moves to a position in front of the drill and is orthogonal to the drill direction
  - The virtual mirror could be locked with respect to the vertebrae after the ideal position is found

Results

	Method	Mean	Std. Deviation	Std. Error Mean
Accuracy (mm)	Virtual Mirror	1.35	0.75	0.17
	Monitor Based	1.7	0.86	0.19
Time (sec)	Virtual Mirror	173.75	84.13	18.18
	Monitor Based	168.95	103.59	23.16

Discussion

- Pros
  - Introduces a new method for navigated spine surgery using augmented reality system
  - Virtual mirror provides more intuitive visualization and more accurate navigation
  - It is more accurate than the classical method

- Cons
  - 2D view guidance
  - Too few experiments (5 surgeons, 8 canals each) to draw valid conclusions statistically
  - Due to the requirement for planning phase, the present method is slower than the classical method

- Future work
  - More surgeon invited to do the experiments

Conclusion

- The paper introduces a new method for navigated spine surgery using augmented reality technology. Although it has its limitations, which are discussed above, it is a successful approach to support more intuitive visualization and more accurate navigation.

Thank you!

- Any questions?

Workflow

1. Generate curvature values for the skin model
2. Calculate the intersection point between skin and instrument
3. Determine the intersection of the line of sight with the skin
4. Calculate the transparency map
5. Render the instrument
6. Calculate the shadow map for rendering instrument
7. Render the virtual datasets into shadow map
8. Render the camera image with alpha blending manipulated with the transparency map